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IN MEMORIAM
FLORIAN CAJORI

WHAT IS BEST IN ENGINEERING EDUCATION?

OPINIONS OF MANY ALUMNI
FROM MANY COLLEGES

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FOREWORD

To those who are concerned with Engineering Education:

In this pamphlet you will find competent counsel on the subject of Engineering Education, from men who have received such education at representative American colleges of engineering and who have subsequently in practical experience observed the advantages and the defects of that education.

These opinions were expressed in reply to comprehensive questions, prepared by the undersigned on the basis of a considerable experience in teaching engineering and in studying engineering education. The investigation was promoted officially by the Tau Beta Pi Association (an honor fraternity admitting only students of engineering or graduates of engineering colleges, and prominent engineers), because one fundamental purpose of that Association is to improve engineering education.

Every man who speaks to you from these pages made at college a scholastic record which ranked him in the highest quarter of his class. He was then elected to membership on the basis of his personality and human qualities. At the time these questions were answered, the men had been out of college for from four to forty years, and had engaged in various kinds of work with various degrees of success. They had various objects in seeking an engineering education, and they have appraised the value of that training according to various standards.

We hope that you will read thoughtfully through the material presented here, and that you will find in it some inspiration and information which may enable you to improve the technique of your teaching if you are an instructor, or viewpoints which may assist you in your administration of educational affairs if you are an executive, or ideas which may enlarge your vision and strengthen your determination if you are a student.

August, 1916.

H. H. Higbie,
President, Tau Beta Pi Association.

THE QUESTIONS*

1. What is your line of work?
   What college and date of graduation?
   See report blank, page 105.
2. Considered broadly, what features of your college life have influenced your usefulness and advancement, or "success," to the greatest extent? 8
3. Which of the things you learned in college, have afforded you the greater saitsfaction in life and the greater pleasure in working? 10
4. What things do you think were not taught well enough in college? What things were taught in college that might well have given place to something else? What studies should be given in college, that are not likely to be given? 53, 59, 61
5. In the development of any scientific subjects that must be taught in college, should the greater stress be laid upon the theoretical foundations, or upon the applications; should time be spent upon developing rigorous methods of thought, accuracy, and mental discipline, or rather upon developing judgment, "horse-sense" and practical perspective? 11
6. Do you think that too much, or too little ground was covered by your college course? Did you have to work too hard, or not hard enough? Would it have been better, as you look upon it now, to cover fewer subjects more thoroughly, or more subjects less thoroughly? Which subjects? Did you suffer much from lack of coördination of courses, too much subdivision of subjects, repetitions or omissions, unwise emphasis, and so forth? Please be as specific as possible. 91, 92, 93, 95
7. How many actual hours per week do you think a student should be present in classes? Are vacant periods between classes useful, or are they likely to be wasted? Is it valuable for students to have vacant periods for "seasoning" their work, or for contemplation? Or would it be better to accustom the student to having every hour of the day laid out for him, and train him to do his thinking "on the run," as he works? What are the relative values of "lecture," "recitation," and "laboratory" work, in your experience and observation? 79, 81, 82
8. Do you favor the method of throwing the student early upon his own resources in the details of his work; or, the method of watching his every step and perhaps prescribing it? What methods do you suggest to conserve and develop any power of initiative, original thinking and ingenuity, with which the student may be naturally endowed? Have you observed any case where a student's college course *retarded* his best development? 16, 18, 21
9. Do you think it advisable to devote the first two years of a college course in engineering *entirely* to preparation in the theoretical prerequisites, or do you think that the ultimate effect would be better if an attempt were made to devise courses in engineering applications suited to sophomore and freshman students? Would college experience be more valuable with the theory given before the applications, or after the applications, or with the two given coincidently and in interdependent fashion? 27

*The number given at the end of the question indicates the page on which begin the answers thereto.

10. What do you consider the object of a college education to be—the purposes for which the time and the energy should be spent—the best fruits of a college training? Is it more desirable to *train young men to think* correctly, thoroughly, quickly, and pleasurably, regardless of the number of facts they learn; or, to lay stress rather upon the value of *knowing things*, and to try to give the student the highest possible money value in his education, *now* in the immediate present? Are these two objects necessarily inconsistent? 13, 14

11. What is your opinion concerning specialization in college courses? Do you think that *engineering* is the name of a special fund of knowledge, or of a practical habit of thought? Have we too many kinds of degrees? What are the chances that a man's life-work will follow closely the lines for which he may have been specially trained in college? Should a college degree be a brand for the type and character and abilities of a man, or rather for a specific amount of special knowledge? 21, 24, 25, 26

12. What value do you attach to a knowledge of, or the study of, foreign languages in the engineering college? Had they better be studied elsewhere? Have you found sufficient use or benefit from your language study, to warrant the diversion of time from other purposes? Is 10% of a college course too much time to spend on foreign languages? Which languages are most important for an engineer? How about study of English? 63, 68

13. How far should mathematics study be carried in college by engineers? Have you regretted spending time on any mathematics for which you have not found practical use in your experience? What branch of mathematics? Is mathematics more valuable when taught rather abstractly, by mathematicians, as a mode of mental discipline, or when taught in a very practical and concrete manner, in intimate connection with its uses, as by engineers, so that it becomes not a subject apart but rather an habitual method of thinking in all things? 72, 73, 74

14. What value do you attach to shop work in an engineers' college course, presuming that the kind of shop work is adjusted to the needs of the profession for which in general he is preparing himself? What kind of shop practice for your own line of work? Is two afternoons per week for two semesters or one whole school year, too much or too little? 104

15. What is the function and importance of laboratory work in a college engineering course? Should it aim to give the student a practical training and readiness in manipulations, or rather to support and clarify the theoretical developments of the classroom and lecture? Should the student there *discover* his knowledge, or *verify* it. 100

16. In about what proportion should the engineering students' time be divided among the following general divisions of study:

A—Mathematics.
B—Chemistry.
C—Physics.
D—English.
E—Foreign Languages.
F—Shop work.
G—Drawing.
H—Engineering studies of a general nature, such as all engineers should know.
I—Special engineering studies along the lines the student thinks he would prefer to follow.
J—Business, accounting, law, economics and other related subjects.
K—Cultural subjects, as history, music, art, etc.

You could render valuable service by specifying in some detail what you think should be the content of each or any of these subdivisions. 40

17. If it be impossible, in the time available, to give all things which seem desirable, which, in your opinion, can be sacrificed with least injury to the student? 47

18. What do you think of the recently developed tendency toward establishing five and six-year courses for engineers? 49

19. Do you think that the number of engineering graduates per year is too large for the welfare of the profession? Would you favor a change in policy in the schools to the end of teaching engineering to only a selected body of men—those who really *want* to *study* engineering, instead of trying to obtain a record-breaking number of students, many of whom are a drag to the others, a trouble to the teacher, and, if graduated, anything but a credit to the profession? 32, 35

AIMS AND METHODS OF ENGINEERING EDUCATION AS SEEN BY ALUMNI IN TAU BETA PI

Collected, Arranged and Summarized by

H. H. Higbie, President of Tau Beta Pi

EARLY in his career, every college man has been made aware more or less painfully that the process of acquiring an education is long and laborious, seemingly always beginning and never finished. This distress does not necessarily indicate that there is anything wrong with the education, or with the process by which it has been or is being acquired; it is usually a symptom showing that the germ is developing normally, the patient being in proper condition to receive the benefits of the inoculation. In fact, education cannot be considered to be even started well, until the student perceives clearly that the knowledge he has, or can have, is meagre and that which he has not is vast; that his powers are very limited even though his imagination may reach far and high; that only through humble consciousness of his shortcomings, and by perseverance and industry, can he hope to make himself useful and his achievements significant.

If our errors and failures and disappointments were interpreted merely as evidence of our own imperfections, and translated into stimulus toward further and proper development of ourselves, therefore, we might well become too busy to enquire to what our faults of preparation are due: whether to our own heredity and environment, or to our education, our teachers and their methods, or merely to the general frailties and limitations of the human animal.

Quite obviously, however, there is opportunity to increase the efficiency of the educational process if, by study of the aims and functions of school training, and the methods employed, we may minimize the inevitable knocks and buffetings of practical experience; there will still be enough of them to keep us in the proper

state of mind, if our training has prepared us to turn them to our own advantage.

I proposed the educational inquiry among alumni members of Tau Beta Pi which was outlined in the April, 1914, issue of THE BENT because, as a teacher, I feel the heavy responsibility which I bear, to make the wisest use of every one of those golden hours which are being invested with me by the students entrusted to my direction. To be sure, I have well-defined personal opinions upon every one of the topics which I proposed—opinions born of many years' teaching experience and study of educational problems in diverse places and with various types of students. But in matters of such far-reaching importance as education, the personal convictions, or interpretations, or hobbies of no one individual or small class of individuals should be permitted to prevail and establish the practice. I feel that it is for the broad mature judgment and experience of the engineering profession at large, rather than the special experience and enthusiastic interest of the relatively small class of teachers, to determine except in limited measure what shall be the characteristics, the strength, weakness, and possibilities of our next generation of engineers.

I think it may be granted that the foundation of engineering education may be effectually inspected and tested in the light of such questions as those which I proposed and published. Every teacher of engineering who loves the labor of teaching, is asking himself just such questions as these, and is trying to answer them according to his best information and judgment, by the methods he employs in lecture and classroom, shop, drawing-room or laboratory. Every student, or graduate of an engineering college, or employer of engineers, must have asked himself some of these questions at some time, after he had labored to understand a difficult lecture or textbook, or to use the education he acquired at college, or to extract the value of such education from other men who had acquired it.

Quite obviously, the teachers have studied these questions more profoundly than other people, because it is professedly their business and chief interest. Nevertheless, the wisest teachers do not

consider their judgment to be final, as may be inferred by anyone who reads the *Proceedings of the Society for Promotion of Engineering Education,* or its monthly *Bulletin,* and notes the variety of opinions expressed upon almost every feature of educational policy and practice. When the questions are so many-sided, the teachers need to have an expression of opinion from every individual who has experience from which to form one. It is plainly the duty of the teacher to study these opinions, experiences and criticisms so that they may be correlated, weighed and acted upon.

Of course, it is not to be expected that on every subject all or even a majority of these opinions would coincide—such possibility would be precluded by natural variation of personalities and environments of men. Then too, the enormous and rapid increase in amount and variety of knowledge which the engineer is required to use, and the ever-increasing fields of activity in which the engineering mind satisfies a demand and earns recognition of its methods, create continually new demands upon education and uncover faults previously unknown because unstressed. Critics are in general self-centred. They are likely to think how much better their own careers might have been ordered, if only they could have received more of a particular kind of training or special knowledge. The deeper thinkers recognize that the educator cannot satisfy such multiplicity of special demands in a first and fundamental course of engineering, unless the students come to college from a practical experience which has developed their bent unmistakably, or unless they have such general education and maturity as will qualify them to select a specialty.

But certainly, no teacher may with reason and impunity disregard the accumulated weight of opinions from a majority of practicing engineers (when such opinions coincide), in preferring his own individual convictions, however sincere they may be. Conversely, when the opinions of the majority of engineers are so much at variance that they contradict and neutralize one another, the teacher may reasonably make his own choice or refuse to be bound by any of the opinions expressed, following his own best judgment. Thus, in any case, a general expression of opinion by

a representative number of able engineers on matters of educational policy and methods, has distinct value. When all discussions are directed more or less toward the same topics, as in the answers to this questionnaire, the educators should be enabled to determine what features should and should not be sought for and developed, or eliminated, in an engineering course at college, and what features the educators themselves are to determine upon their own responsibility. This seems to have been the general opinion of those who answered the enquiry, there being many expressions of interest in the subject itself and in the prospective report or consensus of opinion, as well as many congratulations that Tau Beta Pi had undertaken as an organization a definite and significant service to engineering education. The dissenters were only two or three per cent of the total number of respondents.

I must confess to having a number of incidental purposes in instigating this enquiry. There seemed to be a fair prospect that it would arouse interest in the subject of engineering education in a larger body of alumni than had hitherto devoted thought to the subject. If these live and pertinent questions, brought to the personal attention of upward of 5,000 most able engineers, should stimulate even 2,000 of them to analyze their own experience and formulate their opinions upon the fundamentals and necessities of professional training, a large impetus and potentiality for future development will have been established even if only a few hundred of these men have time or present inclination to commit their views to writing. Further, it is to be expected that teachers may make greater efforts to improve their methods and their courses if it be made evident to them that their work and results—their influence and efficiency, are matters of concern to an observing body of able alumni, whose opinions exert influence upon public and students. Then too, there may be a considerable satisfaction and stimulus for conscientious teachers, as well as a larger measure of confidence and support from students, parents and public, resulting from information or knowledge that the teaching methods and tendencies are examined, supported and approved by a majority of able practicing engineers.

In the report which follows, I have tried conscientiously not to allow my statements to be colored by my own opinions. Extracts from letters received are quoted or paraphrased in such manner as to indicate with minimum repetition the entire range of views expressed, for and against each consideration. I have then given briefly, in my own words, as accurate a summary as I can make of the prevailing opinion. The ground to be covered is so extensive, the material submitted so voluminous (aggregating about 600 typewritten pages) and the interest so keen that I could not do justice to the entire inquiry in a single paper within the necessary limits. Therefore, I have divided the subject roughly into three sections or articles, as follows:

A.—*Function and Value of Engineering Education.* Covered by questions 2, 3, 5, 8, 11, 12. See page 8.

B.—*General Policies in Engineering Education. Arrangement, purpose and content of programs and courses.* Covered by questions 9, 17, 18, 19, 20. Page 27.

C.—*Detail Criticism of Methods of teaching, content and arrangement of courses.* Covered by questions 4, 6, 7, 13, 14, 15, 16. Page 33.

Naturally, the overlapping of questions and discussions makes it necessary to interweave these papers to some extent. In arriving at the majority opinion in questions of broader significance, as outlined in A and B, I have given greater weight to the opinions of older and more experienced alumni, whereas in arriving at the majority opinion in questions of detail, I have given greater weight to the opinions of younger alumni with fresher memories.

I should not conclude this preface without grateful acknowledgment to those who have given generously of their time and effort to express their thoughts, for the great inspiration and assistance which these letters have brought to me personally. I feel that I shall be a wiser and a better teacher of engineering than my own study and efforts could ever have made me without this heart-to-heart talk, this wealth of thought and experience

which I am privileged to study. Earnestly I pray that my greater efforts and achievements shall deserve this privilege.

A. Function and Value of Engineering Education

Question 2. Considered broadly, what features of your college life have influenced your usefulness and advancement, or "success," to the greatest extent?

The following various opinions are arranged in the order of seniority in experience of those who wrote them:

"The patience, the inspiration and wise advice from the able men who so faithfully discharged their manifold duties."

"Training received of the mind, and how to work."

"Mathematical and engineering studies, as I confined myself strictly to my engineering studies while in college."

"Primarily mind training, ability to think and work out problems: a cultivated and trained brain measures the dynamic force of the individual. Contact with strong men of the faculty, and students. The college social life."

"Knowledge of men and affairs."

"If success is defined as an achieved income resulting from college training, I would say the ability to apply fundamental principles and truths to the solution of the practical problems of industry."

"Inspiration of conscientious and hard-working professors."

"Learning to work."

"Development of reasoning power."

"The things which enabled me to get a start at all, as shop, laboratory and drawing. Many men leave college after a few terms and become mechanics or detail draftsmen, occupying positions requiring manual skill and judgment rather than deep learning. These men leave school because of lack of means, or inclination, or ability to finish their course. Students should begin at once to learn useful things that will raise them above the unskilled laborer, should they leave school. These things then most vitally affect the greatest number of men. The engineering college turns out a very few engineers and a large number of skilled workmen: the greatest good to the greatest number should be the dominant idea."

"Work made necessary. Intercourse with hard-working associates. Habit of persistent continuity of thought. Development and strengthening of the faculty of memory. Educational methods of the past thirty-five years at least have taken small account of these things, and those who have either stumbled onto the way or found it by some unusual amount of digging are our big men."

"The acquirement of ability to work efficiently with sustained enthusiasm."

"No particular feature."

"Technical education."

"My college course enlarged my capacity for thinking—largely in terms of the future. My training in school furnished a much-needed foundation which I have used to advantage in studying tendencies of engineering progress, in such a way that it has become a habit to anticipate developments."

"Training in public speaking is most essential in addition to and notwithstanding the requirement of good scientific training in technical subjects. Get as much knowledge as possible, but the ability to express it to others is really the keynote to success."

"Nothing had greater influence for good upon me than the association with teachers, for practically all of whom I held the highest esteem, due to my estimate of their gentlemanliness, and their professional and cultural attainments. I cannot say that this has put more money in my pocket, if that is your intended definition of success: but I believe it has tended to broaden my view of life, to increase my interest in persons and things, to make me a happier man, a better citizen."

"Ability to associate with others, recognizing their limitations as well as my own. Development of ability to 'stick at' a thing until accomplished."

"Thorough grounding in physics, mathematics, and mechanics of materials."

"Training of the individual to solve his own problems, as they appear in his work."

"None, because of the general lack of thoroughness required of students."

"Enthusiasm and inspiration received from teachers. Their pointing out to me that there was work to be done if one was prepared to do it, was what gave me determination to succeed."

"Training of mind to weigh and reason."

"Training in two things: *Promptness* in doing a given piece of work and *System* in doing that piece of work. In college I wrote up my laboratory notes immediately, systematically and thoroughly. This promptness is carried out in this office with my men in their work as much as possible. The habit may have been born in me, but in college it certainly grew."

"Training to concentrate on work."

"Discipline. An active part in college affairs."

"Contact with fellow students, more or less careful observation of their makeup, mentally, morally, and physically. Revision of estimates of my own capabilities (real or imagined at that time)."

"The technical knowledge gained."

Summarizing these various answers to *Question 2,* we find that the contributors fall into two general classes according as they consider of greatest importance (a) the habits formed and viewpoints established in college, or (b) the knowledge acquired and methods learned. The one regards principally the broad and general features of college education: the other regards principally the detailed and special preparation for a particular part of life. The weight of numbers and authority is unmistakably on the side of the former. The prevailing opinion seems to be that college training exercises its greatest and best influence socially, in the traits of character formed by observation of and association with teachers and fellow-students: in inspiration, enthusiasm and determination to work: in development of ability to meet people, with good address and confidence: in acquiring respect for both powers and limitations of other people and self: also, training in independence and concentration of thought, persistence, system, memory.

If these features of college life are most important, it behooves college teachers to spend their time improving *themselves* rather than the content of their *courses*—to look to the morale, habits, discipline, ideals and mental processes of their students, far more than to the exact amount or kind of knowledge they have, or the particular facts and laws they learn. College faculties must be composed of men who are, or will develop into big, strong, well-rounded personalities of high character, and of commanding force or persuasive gentility. These men must exert their personal influences upon the student in every proper manner. They may be general practitioners or specialists, scholars or "practical men," teachers of elementary or advanced courses, either scientific or applied: the one all-important requirement is

that they must be thoroughly *human,* interested in the work of teaching and in the development of the best moral and mental qualities which may be aroused in each student, according to his endowment. They must not do their teaching work in a perfunctory, soulless fashion, considering it either as a mere livelihood or as an inconsequential side issue; but they must display enthusiasm and devotion, for their attitude is contagious in any case. If the teachers are of this caliber, it matters little what they teach: if they are not of this type, it does not avail that they be giants of intellect or masters of large affairs.

Question 3. Which of the things you learned in college have afforded you the greater satisfaction in life and the greater pleasure in working?

This question is answered to some extent in the preceding.

"Research and investigation along engineering lines."

"In general, the broader outlook, manifested by

(1) The ability to lead.
(2) Desire for investigation and culture.
(3) Ability to understand facts and their relations.
(4) A better appreciation of facts and things."

"The book knowledge acquired at college has been one of the factors, and a very wide acquaintance among professional men."

"Applied mechanics, mathematics, hydraulics, water supply and essays."

"What I was not taught at college but learned at a most excellent school—viz., a love for literature and natural science."

"Those for which I have the most natural ability."

"Being able to read and appreciate some of the books and literature published in my line, because of the mathematical training I received. It has also ever been a source of regret that so much was sealed to me because of the mathematical training I did not receive."

"The more fundamental things have yielded the larger return, in every way."

"Contact with scholarly men and their method of doing things, more than any special knowledge acquired."

"Applied mechanics."

"Application of theory to actual work."

"Periods of satisfaction and pleasure which occur now and then after having accomplished a good piece of work. College work is full of opportunities for getting a taste of this feeling of having actually done something, which is a constant inspiration for greater accomplishments."

"Mathematics and mechanics, as I was always partial to these subjects."

"Ability to apply creative ideas."

"The writer believes that the profession of engineering would be benefited and the life history of a good many American boys sweetened, if our engineering courses in the colleges contained more of a general equipment tending to round out character and develop clear, concise thinking, and less of the smattering of theoretical mechanics, mathematics, shop work and laboratory experiments."

"To know and see that in engineering the few main fundamental principles are at the bottom, and govern all work, however complete it may be."

"Planning and designing in connection with my work."

"Love of doing things thoroughly and well."

"The ability to act for myself."

"Close relationship between the laws of mechanics, electricity, thermodynamics, etc., and the laws of mathematics."

"To ponder on the reason why the laws of mathematics when correctly applied will bring us to conclusions which prove in Nature to be correct. There is a guiding, unerring principle that seems to underlie all the sciences: and it is a dim, vague realization of this, that has deepened my awe and respect for the infinite wisdom of our Creator."

Here again, as in *Question 2,* is evidence of the material as distinguished from the spiritual estimate of higher education. Some men get their pleasure from the broader and more general features of engineering education—the truly cultural side if we may use a much-abused term. Another kind of man gets his greatest pleasure out of certain details, specific tasks, which appeal to his particular type of mind. This classification appears to depend upon inherent temperament and personality of the individual, and not upon environment, circumstance, or any factor of education which is within the control of the college. We therefore cannot justly say that either viewpoint prevails, or shall govern. Perhaps we may say that if all the scientific and engineering classes were taught by the right kind of teachers, as discussed under *Question 2,* both types of students would be started on the road to greatest happiness, each receiving the impulse to develop in his own way. The personal influence of the faculty upon the student, in awakening him to the possibilities of each subject and the relations between various subjects, to the possibilities in himself and to the proper development of these possibilities, is of transcendent importance, as from it all other special or individual pleasures and values will grow, whereas the reverse may not be promised.

Question 5. In the development of any scientific subjects that must be taught in college, should the greater stress be laid on the theoretical foundations, or upon the applications: should time be spent upon developing rigorous methods of thought, accuracy, and mental discipline, or rather upon developing judgment, "horse-sense" and practical perspective? The following are typical answers:

"Some subjects tend to develop rigorous methods of thought, while others tend toward practical perspective. Both kinds should be used."

"Neither one nor the other should have greater stress. Both in correct proportions. They are complementary and necessary each to the other."

"Both are necessary for life, for success, for character."

"Greater emphasis on the first. I consider mental discipline as the most important feature of college education. Judgment and practical perspective may come later."

"Great stress on theoretical foundations. Horse-sense cannot be taught in school. Perhaps it and judgment may be somewhat developed. Should develop ability to reason soundly from fundamental principles."

"Theory and application should go together. Development of a proper method of thought or mental discipline will result, with experience, in good judgment or good common sense."

"Fundamental principles should take precedence over applications which change constantly, care being taken, however, to point out the application of the principles."

"Good judgment results only from a thorough understanding of the elements of the question under consideration. It will not do to strain or wear out the mental mechanism in the preparation so that when the test finally comes it is incapable of performing work useful to society."

"Spend the time on foundations and development of the student's mind. Judgment is the result of experience—it cannot be taught. A few months of work will give the boy more of that commodity than he can get in four years of college."

"Stress on important theory and its applications. Judgment will be secured only by developing rigorous methods of thought, accuracy, and mental discipline."

"Theoretical foundations and applications should be taught together in such proportions as best to sustain the interest of the student. The student whose interest is awakened will get ten times the benefit from his study by virtue of that interest, as from day to day he can see that the comparatively dull, uninteresting theoretical subject has a very practical use in the creation of modern engineering works."

"Greater stress should be laid on the practical applications that make the theory useful, and the only part that will be absorbed by most of the students. Too much has been sacrificed to rigor already. Everything the student meets with outside the theory, lacks rigor. Imagine a man unsatisfied by any but rigorous methods, attempting to design any simple structure:—he would never get anything done."

"Both, but especially theoretical."

"Stress on the former. Applications should be touched upon enough to maintain interest and give the student such a fund of knowledge that he will not be considered an ignoramus when he starts to work."

"Stress on former. But there is no particular sense in teaching from books like Rankin or Bowser. Best engineering books have a certain amount of application. Teach accuracy."

"Give student thorough grounding in the theory he will need. The practical application of this theory should occupy only a small proportion of the total hours."

"As much theoretical foundation as possible while one is in college so as to have the benefit of the professors' instructions."

"If a man does not get fundamental theory while a student, he will never get it. Practical applications give interest to the theory, but will come easily later."

"Time spent in laying stress upon the applications at the expense of theoretical grounding is lost time. However, I believe that applications of theory should be cited every day and that the problems which are given should be as largely practical as possible. The development of the judgment, etc., is important and it seems to hinge largely on the personnel of the teachers."

"There is a happy medium. When the student reaches the engineering subjects, his instructors should be men who possess a very broad and practical knowledge of the subjects which they handle, and be able to convey this knowledge to the student. Under these conditions only will theory and practice be properly united in the mind of the student. Horse sense is very close to truly applied theory."

"Correct foundation most important. Judgment and horse-sense are a part of the individual and cannot be taught."

"Greater stress on developing judgment, horse-sense and practical perspective."

"Too much stress cannot be laid on getting fundamental theory well grounded. But these plain fundamentals must be made so clear by application that one can always go back to them and work out the solution to any problem."

"Universities cannot make practical engineers. The most they can do is to give theoretical grounding and this should be the main object of the college course."

"Answer depends on student's inherent characteristics. If he is practical he needs theoretical training, and vice versa. I think the general average need a little more horse-sense."

The consensus of opinion seems to be that the college courses must be designed to give the fundamental theoretical work very thoroughly as far as it is likely to be useful. Applications should be given coincidently, in parallel courses or preferably in the same course and at the same time as the theoretical treatment. Constant practice should be given in the solution of practical

problems from the fundamental theory, giving the student self-confidence and interest. Judgment and common sense may be fostered in college but depend primarily upon the temperament of the student, and upon experience which is best acquired outside of college. These qualities are likely to develop easily in those students who have had a thorough and interesting course in theoretical elements, and discipline in accurate and consistent habits of thought, under instructors who have practical experience as well as interest in teaching and in the individuality of the students.

Question 10a. What do you consider the object of a college education to be—the purposes for which the time and the energy should be spent—the best fruits of a college training? The following are typical answers:

"The greater training of the mind: the obtainment of useful information and knowledge: one's limitations."

"I think there is no question today among educators as to mental discipline being the principal object of a college training. If at the same time, the student may acquire some practical knowledge, so much the better."

"Correct and logical methods of thought: culture of mind: knowledge of how to study and to pursue investigations. Facts follow and if lost the student always has means of getting them."

"From a selfish individual standpoint, the best education is that which will enable a man to make the most money for the least effort. From the unselfish standpoint the best education is that which makes a man the most efficient in advancing society. These two propositions are inconsistent and antagonistic."

"The object of a technical school should be to educate a man, not merely to fill his brain with formulas or to teach him to use certain tools: to give him a broad foundation on which to build his experience: so to teach him that he may be able after graduation to mingle with educated men as an equal. If he is to make any great success in his profession it will be through acquaintance with men who are not engineers. They will judge him to a large extent by his knowledge of things and men and not by his technical knowledge which they are not capable of understanding. He must have the latter, but it is almost useless by itself. Many men of the highest technical knowledge have failed of success because their lack of education was apparent to the men of influence whom they met."

"I hold that the object of college education is to provide society with trained, skillful, efficient workers—workers with both hand and mind. We believe that everyone should be educated and developed to the full extent of his natural limitations. We can imagine a time coming when all members of society will be college-trained. Some one must do the world's manual labor, and any institution that proposes to prepare only a few to supervise and direct the activities of the many is not founded on a rock. It must give way to that institution which aims to accomplish the broad purpose of the highest universal education. The college should take all who apply for instruction: should invite them in: go out into the highways and compel them if such a course were possible."

"A man goes to college to get theoretical education. He will get some facts, but these are unimportant. He also goes to college to learn how to associate with gentlemen. If he gets one of these without the other, he lacks a good deal that he ought to have gotten."

"Teach men to reason. Things assumed as facts today may be out of date tomorrow, but ability to think and reason correctly is an accomplishment that will serve in any line and at all times."

"The object of a college education should be to unlock the door to knowledge, train the mind to correlate theory with practice, awaken a desire for study."

"The prime object of a college education is to teach students fundamental principles and to develop in them the ability to think logically and thoroughly.

At the same time, each graduate should have been thoroughly taught some subject or subjects that will give him an immediate positive commercial value, moderate though this value may be. Such a training will help him much in self-confidence and give him a manly feeling of usefulness in the world."

"Should give a man exactly what he needs to know in his chosen line of work."

"A man should leave an engineering school with independence, self-reliance, a certain amount of special information, and a knowledge as to where to find other information that he may need. A varied practical experience is valuable, and summers during the course should be made use of."

The majority believe that college training should develop in the student, above all, qualities of mind and character which shall enable him to take pleasure in all work which he may be called upon to do, and to find that work for which he is particularly suited: to make the most of his endowments, and to be both ambitious and contented. He must be trained thoroughly to proper habits of thought, and shown how to proceed toward making his thought useful and productive. He must acquire a creditable address. The amount of knowledge or degree of expertness gained is of secondary importance. It is not right, however, that students be permitted to leave college with so little knowledge of fact, or of practical affairs and the use of their equipment, that they appear at disadvantage in comparison with untrained men: for this impairs their confidence and self-respect, and subjects both them and the college to unjust ridicule which, though temporary, is often humiliating. Given the proper kind of men as teachers, it is more reasonable to expect the college to give this training of character and of mind, than to expect it to impart expert knowledge.

Question 10b. Is it more desirable to train young men to think correctly, thoroughly, quickly, and pleasurably, regardless of the number of facts they learn: or to lay stress rather upon the value of knowing things, and to try to give the student the highest possible money value in his education, now in the immediate present? Are these two objects necessarily inconsistent? Typical answers:

"Young men should be taught first to see and then to think. The question of facts acquired will then take care of itself. A man that sees and thinks will keep on acquiring facts long after his college books have been discarded. Methods of learning used in colleges should, to a reasonable extent, harmonize with the ways and means of obtaining knowledge in real life, so that the graduate may continue to grow in a natural way."

"For the average engineering college student, both are essential. These two objects are not necessarily inconsistent."

"The immediate money return from an education when a student graduates should be subordinated, as there is too much of a tendency nowadays to try to make skilled mechanics, rather than engineers, of our graduates."

"The former, certainly: but not regardless of their ability to memorize permanently. The two objects are not necessarily inconsistent."

"If you consider engineering a profession, educate your students: if you believe it to be a trade, teach them."

"If possible, the teacher should be practical, as well as theoretical. It is no doubt true that the teachers in many institutions are not as expert as they should be, due to the small pay as compared with the pay of manufacturing establishments for men of equal ability—this may be changed during the next ten years. If the courses 'lean' at all, it should be toward the practical. The student should be trained to think quickly and correctly, and to know a few things."

"To think thoroughly, correctly, and independently is the highest mental accomplishment of men, and therefore should be the ultimate aim of education: but the college should begin by teaching men to do and know things (for many will get no further than this), leading such as are able onward and upward toward the higher and better things."

"For most men the immediate realization of both objects would not be possible. The choice of the first makes immeasurably more for satisfactory living, and ultimately for success."

"Not necessarily inconsistent, but development and training are infinitely more valuable than an accumulation of facts. One of the most valuable courses I took in college was a short course for architects in surveying by Professor Ira O. Baker, not for the knowledge gained but for the way he taught us to do things."

"The objects mentioned are not inconsistent, provided that 'immediate' means not less than three years after graduation: for a mechanic with a trade school training can earn more than an inexperienced engineer."

"The student should be made to realize that all work has a definite goal and he should be taught the shortest path to reach that goal. The greater the number of facts that a person can retain in his memory the greater his knowledge of the particular subject, and therefore the greater his efficiency. These facts should, however, be ready for use and should be sure of a practicable purpose. . . . . The one great fact that ought to be impressed on all students is that after they have graduated they must still serve an apprenticeship to round out the knowledge they have obtained."

"Train the student to think: give him a good foundation on the theory. You can always go to authorities to get the details, and hence there seems no necessity for loading the mind by remembering things. Let the student know how to apply the things he can find in the different authorities. He will soon learn those things belonging to his special subject."

"The object of a college education is probably different with each and every man who goes to college, and in many cases the object is not very definitely in mind. I believe it is most desirable to train men to think accurately, quickly, and deeply. If a man wants to be prepared to make his living as soon as possible he must be taught to use the tools of some one profession in which he will naturally be a laborer unless he has initiative or executive ability. If he has not initiative or executive ability he will always be a laborer whether in the shop or in the office."

"Train them to think correctly regardless of the facts they learn. Actual things learned are unimportant."

"The student should be taught the power of analysis."

"It is decidedly more important to train a young man to think correctly, thoroughly, quickly and pleasurably. Facts, however, given in a timely manner, make thinking more pleasurable and aid in the other characteristics. A mere informational course would be not only immediately incomplete but would lack much in training for future usefulness. It is not at all inconsistent to link these two factors together."

"It is more desirable to train the student to reason accurately and think quickly, starting from a few basic principles."

"The former, decidedly. The latter is not necessary nor valuable if the student knows fundamentals. These two objects are inconsistent as a general rule."

"Both can be learned at same time. An engineering course is necessarily one teaching specific and definite information and methods."

The composite opinion seems to be overwhelmingly in favor of training young men first to think, correctly, thoroughly, quickly, and pleasurably. My adjectives were repeated, either consciously or unconsciously, by so many correspondents, that it is evident they describe very accurately the kind of thinking which is de-

sirable. If the memory can be trained to retain facts without jeopardizing the ability to assimilate them or to weave them together and draw conclusions, a large advantage is added. A man who has learned to think, however, has acquired the greater control over his own future. The larger ultimate value of college education will be attained if the immediate value be not considered. Without sacrifice in this respect, some courses at college may be arranged to teach well a few practical things which give the student an immediate earning capacity: properly administered, such courses may, in fact, increase the interest of the student in his work.

Question 8a. Do you favor the method of throwing the student early upon his own resources in details of the work, or the method of watching his every step and perhaps prescribing it?

The following typical answers are arranged in the order of seniority in experience of those who wrote them:

"During the first three years, the student should be pretty carefully guided in methods but in the senior year may be given some problems of research in the laboratory where he can map his own course. This can be still further developed in the thesis work. I consider the opportunity for initiative the principal reason for preparing a thesis. If he has any talent in this direction, it will show itself under this plan."

"Middle course is preferable. Depends upon age and class and subject."

"Student should be put as far as possible on his own initiative and carefully though conservatively, lead towards this end: original thought and logical development. Instructors should be on the lookout for and encourage development of original powers."

"Yes, place him upon his own resources as far as possible. Require him to make frequent reports well written in the fewest words possible with no essential omission or superfluous exposition, illustrating as far as possible by freehand sketches. For instance, let him travel over a three mile prescribed course, studying the topography and geology and from this observation make a geological section and profile, naming the various rock formations, their dip, and give reasons for these conclusions. These will generally be wrong, but the training is good nevertheless."

"I believe in compelling the student to work out his details in great part, so as to develop originality and thought. The general tendency of the student is to lean upon the instructor."

"Throw him early on his own resources *in details of his work.*"

"Give student definite and exact instruction as to how his work shall be done. This is what he will get after graduation in any well-regulated office. Start him right. If he has ingenuity it will come out."

"Put the student on his own resources, but watch and be always prompt to guide or check him."

"The student should have an outline to work to, but should not be guided too closely as we learn more by our mistakes than by our deeds done right. This does not apply to languages, mathematics, etc."

"I believe that the student should be early thrown on his own resources but that at the same time he should be constantly watched to see that in so doing he does not fall into error. At the very beginning of his course he should be trained in the use of the library to find out all that has been written on the subject for the purpose of avoiding the needless duplication of experiments. He should be carefully trained in the interpretation of the results of experiments by others. He should be taught to determine clearly in his own mind what facts are to be sought in his own experiments."

"I do not favor leaving the student to his own devices very early. There is a certain technic to be acquired, an acknowledged best way of going about things in shop, laboratory and field that should first be acquired. If he finds a better way later on, well and good, but don't let him begin in a way known to be bad."

"If you throw the student upon his own resources, he will obtain a long line of zeros. Lay out the work for him and later on if he has any initiative it will come out; but if he hasn't any he will never get anywhere unless it is laid out."

"I have observed cases where work under too much supervision has retarded development."

"Much time is lost by students because the advance lesson is not explained and the difficulties smoothed out so students could make progress. Help them on theory, and start them applying it at once, they doing the actual work."

"Few students are well enough equipped fundamentally or with practical experience to accomplish much when left entirely by themselves, one might even add when only moderately guided."

"It seems to me dependent on the student whether he should be guided or thrown upon his resources early in the work. Some men will develop proper methods; others will flounder around hopelessly. If it were possible to study the individual, it seems to me such should be done."

"As early as possible the student should be thrown upon his own resources."

"Yes, but he should not go so far that he may be discouraged. . . . . I do not believe in 'cook book' engineering instruction."

"I do not believe in throwing the student early upon his own resources in details, but I believe that his power of analysis and ingenuity may be developed under the exceedingly watchful eye of a good instructor. I do not favor much an elective system and would have fully three-fourths of the subjects prescribed."

"A student thrown on his own resources in working out the details of a design will respond quicker to any defects pointed out to him after the design is finished than before. He is in a better mental condition to receive information after having the problem fixed in his mind."

"The student should be thrown upon his own resources to the greatest possible extent and should be assisted only when it is absolutely impossible for him to advance further alone."

"I have seen so many men doing important engineering work who are not technically trained engineers, and other very good engineers who have been students at what are ordinarily classed as low-grade institutions that I have come to the conclusion that, in order to achieve the highest success, all engineering education should be designed to develop character, personality and common sense. I believe that anything in a course of training which tends to throw the student on his own resources and to develop whatever force and originality he may possess is far preferable to a method of watching the student's every step and perhaps prescribing it. In fact, I cannot imagine anything that would be more harmful to a man's development than such a course."

"A student should always be thrown upon his own resources. That is the only way he develops."

"Some men should be thrown almost entirely upon their own resources. Others should be watched. I think that the good instructor should study his men as well as the subject which he is teaching."

"A student should be carefully watched and guided in work that is habit-forming. After a habit is formed he should be thrown on his own resources in order to form the *habit* of self-dependence in using his acquired power."

"It is necessary to watch the student especially in the first two years, and to prescribe his every move."

"Too much time is wasted by students trying to develop a method when a very slight assistance will start them on the right track."

"The average student needs a certain amount of guidance in his work, particularly during the first two years. I believe his instructors can do a great deal toward stimulating his interest in his work by showing a wholesome interest in him and in the subjects they teach."

"The student should not be thrown upon his own resources. He should be trained to think and perform in the most direct method. He should not be allowed to think in a slipshod manner or to work out ingenious ideas rather than master the subject in hand."

"Some people have to be led all their lives, while others refuse to be led almost from the age of reason. These two classes of people to my mind require radically different treatment in educational matters."

"The average student in his junior year—the year when he starts his professional studies—is still too immature to be thrown entirely upon his own resources.

This condition might be changed if his previous training were of a different nature or if the poorer students were weeded out more stringently. As a matter of fact, the poor student is nursed along to such an extent that he becomes an important consideration in planning the work."

"The student should receive no help in solving a problem until he has had a considerable length of time for study of it."

"By all means throw students upon their own resources. Not only will this strengthen men having latent engineering ability, but it will hasten the elimination of the unfit."

"Throw him on his own resources as far as possible. There is often more than one way of doing a thing."

"Force the student to rely upon himself in all his work. With this method, any student not worth carrying along will be forced to drop out, which I think would be for his own good."

SUMMARY: The discussions submitted on this point were so complete, so able, and so diversified that they have been quoted very fully; thus it remains the function of the summary merely to express the emphasis of the repetitions not quoted. The weight of numbers, experience and authority favors throwing the student upon his own resources in the details of his work, but always after some preliminary instruction in approved methods, and always under the watchful eye of an able, interested and sympathetic instructor. There are undoubtedly two general types of mind to which the instruction must be accommodated, and to this fact the diversity of these opinions is probably due. Inasmuch as each type offers possibilities of great value, and has a right to life and to its highest development, we must place upon the teacher a responsibility to study these possibilities, and to realize them in each type to the fullest extent possible.

Question 8b. What methods do you suggest to conserve and develop any power of initiative, original thinking and ingenuity with which the student may be endowed? Typical answers as follows, in order of seniority:

"It is important to encourage the tendency of the younger graduates to keep in touch with their college through correspondence relating to technical matters, particularly real working problems which come up for solution. The college should appoint a curator to receive and classify these problems in such a manner that they may be used by the professors in the classroom to excite the students' interest and keep the college work more in touch with the world's work."

"Employ trained and competent teachers."

"Compel the student to work out his own details."

"Certain model exercises should be prescribed with each step formulated and watched in the beginning of a student's course; thereafter original problems should be assigned on which the student is to use his own ingenuity."

"No method can be suggested of developing powers of initiative, etc., as each case requires individual treatment. Encouragement should always be given."

"The student should be required to do his work very systematically and reach his conclusions by very definite and clear steps, but he should be encouraged to develop his own system, and to reach his conclusions by that process of reasoning which his own mind most naturally follows; and the teacher should himself be sufficiently teachable to appreciate true reasoning and a correct conclusion no matter what course it may take. Most of our methods of representing facts and relations of fact are necessarily arbitrary, but the teacher must recognize that *his* arbitrary way is probably not the only way, and possibly not the best one, if he is to develop initiative and originality in his pupils."

"The best way to learn to swim is to be 'pushed off the dock.' Just as is done in actual work, if an organization is successful, 'put it up to the man and hold him for results.' You can't expect action if you hold a man's hands all the time."

"Give him practical problems to solve. Make him realize that the engineer, above all men, must continually apply judgment in his work."

"Probably the drawing room offers the best chance to bring out original work. My practice is to let any student who shows signs of ability to carry out original designs, do so. With large classes this is difficult, and sometimes it is questionable whether it is for the general good."

"Seniors should work on an original thesis most of the year all afternoon."

"It will be time enough when out of school to follow up original analysis and ingenuity."

"The instructor should consider it one of his duties to develop initiative. I think an occasional hypothetical set of conditions and limitations handed to the student as a problem involving his judgment, would if well and thoroughly followed up develop that initiative. Such a problem once issued should be hung right onto and thoroughly threshed over."

"In general my feeling is that a constantly decreasing minimum amount of direction is the only sure way to develop the students' own ability. In general, the four-year period of prescribed work in college or technical courses tends to reduce initiative and original analysis. Some of this reduction is of course the curbing of more or less ill-directed impulses and notions. But I think it quite frequently the case that the amount of initiative at the end of the four years is rather below normal, although it *may* rise to a much higher value later on."

"The principal methods available are first, the thesis, and second, laboratory work and original problems for which the students are expected to develop their own application of theories to the greatest possible extent."

"The development of initiative is a problem to be met by the individual instructor according to the nature of his work and no rules can be formulated therefor."

"In all laboratory work encourage original experimenting as much as possible rather than following a set course of tests."

"It is desirable that a man should be placed upon his own responsibility to the greatest degree possible in order to bring out the qualities you mention. Teaching engineering has some similarity to teaching swimming. An instructor might try to teach swimming by the simple method of telling a student to kick his legs and paddle with his hands and then throwing him into the water to sink or swim. Another way is to tie a belt around the student and fasten a rope to it by which the teacher can drag the student out if necessary, and then watch the efforts of the learner, correcting mistakes of form as they show themselves. The man of courage and determination would learn to swim in either case, probably better and quicker under the first method than under the second. We don't need to worry about him, however; our attention is given to the average and the poor students who need careful coaching and a timely tug on the lifeline."

"Give the student practical problems without prescribing a method to be used in their solution. I have known students who could solve almost any problem when they knew the method to apply, but were up in the air when thrown on their own responsibility."

"Give practical problems requiring analysis before attempting solution. Instead of stereotyped laboratory experiments, have students work out the method of attack, i. e., leave it to the student to prove or disprove experimentally, propositions having had classroom discussion."

"Business men and engineers are constantly telling me that college men have no originality. Give a college graduate a piece of work to do and he immediately wonders if he can get a book and 'read up' on it. He 'reads up' and then thinks (if he thinks at all). He ought to *think first* and then read up."

"Frequently asking why certain steps are taken will show whether students are thinking or remembering. Let students do problems (in mathematics, for example) any way they can, rather than prescribe a certain method."

"Problems and opportunity to work them."
"Searching for information outside of the regular textbooks, is good experience."
"Give him original problems, presented on the spur of the moment and from a different angle than he has been accustomed to see it. Give him practice in recognizing it when it is disguised. Best form of test for an engineering student is to give problems containing special kinks, allowing him to use all the books he wants."

SUMMARY: To develop originality and initiative, the prime factors of progress, is a vital problem and a critical test for the teacher. Specifically, on account of natural variations of temperament, each student presents a different problem; but generally it may be said that all students should be exercised in trying their own powers of offense and independent attack. All the ordinary vehicles may be used to convey these lessons in self-reliance, when subject to the guidance of the competent and interested teacher; the magic spring which operates them all is *problems*. In the drafting room, we may have problems of design; in the shop, problems of construction and execution; in the classroom, problems of practical application of fundamental principles or of deduction of principles from practical experiences; in the laboratory or field, the problems are in the determination of procedure, and in the analysis and interpretation of observations. In any case, the problem is a strife of undeveloped thoughts, in which the fittest survives and becomes productive, begetting self-reliance, with satisfaction in activity. Thus, too, is the imagination developed, which clothes all facts with beautiful possibilities and all tasks with some kind of pleasure.

First of all, the teacher must be interested in studying men—his pupils—as well as things—his science. Then, he must have such intimate and profound knowledge of his subject and sufficient experience in his profession, that in the activities of teaching he may concentrate his attention upon his methods of presentation, his pupils and their individual characteristics and difficulties, rather than upon tomorrow's lesson or the problem for next week.

To me, the strangest feature of all the answers was that no one said originality is born in a person and cannot be cultivated! Having read this statement with reference to "horse-sense" or "common sense" in many answers to *Question 5,* I thought there

was even more reason to expect it in reference to such distinctive qualities as originality and initiative, which are at least equally rare.

Question 8c. Have you observed any case where the student's course at college retarded his best development?

Typical answers are:

"Yes, occasionally—as you intend the question."

"The course of life which the student follows may retard him, not the college course."

"Yes."

"No."

"We 'teach' too much. There are many who have retarded their own development, but—."

"When in class with much slower students."

"I have often observed students in an engineering college who would have made good doctors or lawyers, but whose education along engineering lines would never make them engineers."

"Where classes are large, a course must necessarily be arranged for the average student. The better students in the class are apt to be retarded in their development in such an average course. This can be overcome by encouraging such students to take extra elective subjects."

"I doubt whether any student's development has really been retarded by his course. That probably has been used as a handy excuse in cases; but doubtless, if that excuse were not available another equally high-sounding would have been found."

SUMMARY: Very few opinions were expressed on this point—so few, in fact, that it would be illogical to attempt to draw any conclusion from them.

Question 11a. What is your opinion concerning specialization in college courses? Have we too many kinds of degrees. Typical answers, arranged in order of seniority in experience:

"There is only *one kind* of an engineer, except the good and the bad, and he is the man who is engaged in 'directing the great sources of power in nature for the use and convenience of man.' A mistake is being made in all our American colleges, except the few which devote themselves to a single course, such as Rensselaer at Troy or Stevens at Hoboken. In other professions, such as medicine and law, no such differentiation is made in the college course. In brief, my suggestion is that our universities should turn out men with a single degree, and preferably that of Bachelor of Engineering, because a young man is not an engineer when he graduates any more than one is a lawyer when he receives his degree; and secondly, that the courses should be arranged electively, allowing the student to select for himself."

"There is too much specializing in the engineering courses. In this respect a hint should be taken from the lawyers and the doctors, who do most of their specializing after graduating from general courses. In all branches of engineering there is a great dependence on mechanical appliances. Hence, it might be well to make general mechanical engineering the basis of a broad course which would fit the student to take up civil, electrical or mining engineering, as opportunity might offer.

The specialized graduate may overlook good openings in other directions, and this too often largely through pride.

Specialization for commercial work is, with certain limitations, best obtained later in life and when there is more reason for the choice. Highly specialized graduates are sometimes seriously handicapped at the start of life's race by knowing too much. Detail knowledge, if unwisely put forward, makes them unpopular.

Moreover, there seems to be such a thing as going stale mentally, just as the overtrained athlete goes stale physically."

"I believe the tendency is towards too much specialization. I think if a man is thoroughly grounded in language, mathematics, physics, chemistry and applied mechanics, he will be able to do engineering work quite successfully even if he does not get the specific engineering training."

"A certain amount of specialization is necessary on account of the demands of the industries, but there seems to be a tendency to over-do this. Specialization along the broad lines of engineering is necessary and options should be provided during the latter part of the course for mature students, who know definitely what their work will be upon graduation."

"I do not believe in specialization. Develop the student's mind and instil fundamentals; he can then pick up the special knowledge required for the line of work in which fate throws him."

"Specialization should be reserved for the graduate students."

"In actual practice the demand today is more and more for specialists. It is becoming very difficult for an engineer who has acquired experience in one particular line of work to obtain work in any other line. The chances are very great that a man's life work will follow more or less closely the lines for which he has been especially trained in college, although of course there are many exceptions.

"Except to a college professor, degrees are of no value. No man in engineering can stand on a degree and personally I hate to see an engineer put a degree after his name. The courses are all right as they stand."

"I favor the single degree of Bachelor of Engineering for the first degree, with the professional degree of E.E., etc., as an advanced degree comparable with the Master's degree and implying at least a year of specialized work."

"The student will gain more by four years devoted to the study of the underlying principles of commerce, and technical business, than he will by devoting the entire four years to the minute analysis of highly specialized subjects."

"Sometimes I think the word 'engineering' for a college a misnomer—for, honesty, engineers are not made in the schoolroom. We can train technical men, but whether or not they become engineers depends upon their experience after they graduate . . . . . I find myself growing more and more in favor of a limited number of degrees and eliminating as far as possible 'specialization' in the college course."

"I strongly favor specialization of courses. Even at the present time, every engineer finds that his profession has too great a scope for him to be master of the whole of it, and circumstances usually compel him to specialize in one or more branches."

"I would not specialize too much in engineering courses. The writer makes use of his engineering training every day, and yet is not practicing that as a profession."

"Unfortunately or perhaps fortunately most men who come to these courses are not so qualified or prepared as to make all-round engineers or to occupy any engineering position with credit, even after any amount of college preparation. The average man will merely learn the use of the tools of some one engineering profession and perhaps most of them are equal to only such a course and development."

"The answer to this question depends somewhat upon the path chosen after leaving college. We might make a general statement that the whole time might best be spent in digging out such knowledge as would be most pertinent later on. But the longer I labor, the more I see of the work to be done and the broader becomes my acquaintance, the more use I find, and value too, for the things taught which at the time seemed of little account to the engineer. There is no other profession in which a broad education stands to one's need so well as in that of engineering, for to be successful one must meet with and be able to interest men of all walks of life."

"We give too many degrees. Considering the age and experience of our students, our colleges allow too much specialization. It is unnecessary, as few students know what their life work will be. I advocate the most general courses. For the majority of students, the best place to specialize will be on the job, in business."

"Degrees should be abolished. They are no indication of a man's ability or learning."

"Principles can be taught from applications in various special subjects. If a student in his senior year has a decided leaning towards a certain specialty he will gain more of principles that are illustrated in this subject. I believe that most specialization, however, should be done in postgraduate work."

"A certain amount of knowledge of the laws of physics, chemistry and mechanics is an absolute necessity for an engineer, but more important still is habits of thought,

i. e., his ability to apply these laws to the solution of engineering and practical problems and to foresee new applications. In spite of the increasing number of technical societies covering a specially designated branch of the field of engineering, I think the tendency in regard to the giving of different kinds of degrees should be towards their reduction rather than their increase."

"I attach very little value to college degrees. One is as good as another. The courses are very much alike—at least they were when I was in college. Special knowledge should be gained in practical work."

"It has been our experience that very few students in college have a definite future laid out, more than a hazy notion that they want to be electrical engineers or mechanical engineers or some other class of engineers, not realizing the full meaning of the term in any way. . . . I believe that men taking a general engineering course, covering thoroughly the fundamentals of mathematics, mechanics, etc., and spending very much less time on special or technical subjects, would have a much better chance to succeed because they would be better able to adjust themselves to any opening that may occur after leaving school. They would have a foundation upon which to build up almost any line of engineering work."

"I believe an improvement over the present system, would be a plan by which a student after a period of theoretical training, say two years, could spend the next two years in actual business, actual contact with men of his profession who are earning their bread and butter. Then after he has found his place or struck his gait so to speak, let him return to college and resume his work along the lines with which he is familiar and expects to continue in life. The principal obstacle to this plan is that once the young engineer has acquired a foothold in his profession he is loath to let go. Very few graduates make enough money in the first two years out of college to carry them through two more expensive years of study."

"Specialization is the thing. The last two years should be given to the student almost entirely—under proper guidance, of course. Economics and law are two of the studies to be chosen as electives. Foresight in choosing the special course is the most fortunate thing that can happen to a student."

"There should be a certain amount of specialization in engineering courses, but not to a fine degree. I graduated as an engineer but am now a patent attorney."

"A good working knowledge of fundamentals, sound reasoning powers, and a healthy perspective are necessities, and with these the graduate is equipped to follow such lines of work as chance may dictate. In practical life, specialization is usually the result of uncontrolled circumstances, and is seldom due to any special undergraduate training."

"Specialization is becoming more and more important, but is not entirely practicable for the student because he does not know along what lines his future will be laid."

"A reduction in the number of degrees would increase the number of subjects in the remaining degrees."

"No specialization with high school graduates. All engineering courses should be the same until at least the third year. Then the student will have found what he really likes, and should be allowed some choice in his studies."

"Depends upon the student's previously acquired knowledge and training. The broadest possible training should be given, to acquaint him with the basic principles of a large number of different subjects."

SUMMARY: The views expressed were many, significant, and interesting, and the quotations represent them quite completely. As I study and weigh them all, including the repetitions which do not appear here, I am definitely impressed by the conviction of the majority, that there is not more than enough time in the ordinary college course to lay a good *foundation* for engineering work—to acquire by thorough drill the fundamental principles which are common to all branches. What the world wants is *men*—thinkers and doers—who can and will adjust themselves to the work that is to be done as it opens up. If the college should train men to use

a few simple tools exceedingly well, these men could turn out wonderful work in almost any line. One good purpose really served by such slight specialization as may be permissible in engineering colleges, is to enliven the interest and thereby increase the achievement of the student, by choosing suitably the medium in which he cultivates and studies the fundamental principles.

Question 11b. Do you think that engineering is the name of a special fund of knowledge, or a practical habit of thought?

It is not desirable to quote from any of the replies, because the phraseology of my question was so generally accepted and copied that the answers were rather uninteresting and monotonous. The opinion was practically unanimous among those who answered, that engineering is a practical habit of thought, and not a special fund of knowledge. This being the case, teachers should develop the curricula, the texts, exercises, and all other details of instruction, in such manner that the student shall be induced and compelled to acquire good habits.

It is generally agreed that the difficult features of engineering practice and engineering instruction are not in the finding or acquisition of knowledge, but rather in the translation, interpretation, or application of it. While reasoning power, memory and experience are very valuable, they cannot assure success in practical engineering work unless combined with certain other homely accomplishments—such as "putting two and two together," and "killing two birds with one stone." These habits of economy in the use of time, of energy, of mental effort and of all the tools with which engineering works are produced, may well be started by a wise instructor. The student may be trained to observe the *meaning* of an equation as much as its *form,* to express in English the results of varying certain factors, or to translate quickly at sight from a written specification to a mathematical form of expression. He may be required to project rapidly several methods for solving the same problem, and to decide which method promises the greatest economy of necessary time and material, of data and effort. If habits are more essential and fundamental

than knowledge, it is certainly the teacher's responsibility to study the form of his courses and the characteristics and methods of his pupils, rather than the extent or contents of the courses and the mere achievements of the pupils.

Question 11c. What are the chances that a man's life work will follow closely the lines for which he may have been specially trained in college?

"The young man entering college rarely has any idea as to the specific work which he proposes to follow later. The college course, certainly for the first year and possibly for the first two years of a four-year course, should be obligatory in its details."

"Chances are 60% to 75%."

"Chances are in favor of man's following fairly closely the lines for which he has been specially trained in college. There are many exceptions to the rule."

"Chances are about 50%."

"Majority of men do not follow closely the lines for which they were specially trained in college, but the general training helps them in the course that they pursue."

"Few men know what their life-work will be."

"Chances not great."

"My classmate whose name came next before mine on the roll did not stick to electrical engineering more than three years. Now he is running a scientific poultry farm. Few of us are able to make our work fit our training, we must make our training fit our work."

"I graduated in electrical engineering, but am now a patent attorney. I use my engineering every day, but do not believe my work follows very closely the lines of my college training. Among my acquaintances there are dozens like myself."

"A man's life-work is the result of two things, his natural inclination and his training. If the two coincide he follows his training strongly. If they do not he follows his bent (usually). Efficiency demands that the two be made to coincide."

"If a man has worked hard in the field a year or two before or during collegiate course and has had opportunity to see various kinds of engineering work, the chances of following his line are good."

"Few really know while they are in college—they *think* they do."

"The least able will follow it closely in an uninspired uninspiring sort of way. The most able also, because they go along the line for which they are best suited."

SUMMARY: The number of opinions expressed was hardly sufficient to warrant any general conclusions. Of those who did express an opinion, quite clearly the majority believed that the chances were rather against than in favor of the coincidence of occupation and preparation. In collecting the data from the letters, I was interested in noting the variety of present occupations of the writers, all of whom must have studied engineering with such enthusiasm and ability that they stood near the top of the class as to scholarship. These occupations, selected at random, were clergyman, fiction writer, manager of a laundry company, farmer, teacher, physiologist, secretary of Y. M. C. A., executive.

Here, obviously, is another reason for making our college courses in engineering as broad and as thoroughly fundamental as it is possible to make them. Students without experience who clamor to be given special knowledge and training at the sacrifice of essentials, do not know what is best for their own future, and they should be denied. Advanced and technical courses are for the mature student who has found from experience where his bent lies and what his work will be. Engineering methods, of measuring, of thinking, of doing, will achieve the best results in many lines of endeavor outside the field ordinarily considered to be engineering; and if the prime courses are sufficiently broad and fundamental they make better preparation for life than law courses or purely cultural courses. If we force too much specialization upon the student at the expense of these principles, we shall seem unworthy to face a great opportunity.

Question 11d. Should a college degree be a brand for the type and abilities of a man, or rather for a specific amount of special knowledge?

Typical answers, arranged in approximately the order of seniority:

"A college degree should indicate what a man is fitted to learn. It should not be considered as a sort of pure food label."

"Both, skill and ability also."

"It should be a certificate of character and ability and a particular line of training—not for a specific fund of special knowledge."

"It should of course indicate training and ability as well as knowledge."

"A college degree should stand for a trained man in science, English, and mathematics, with a certain definite preparation along one of the general broad engineering branches."

"It would seem that the subject of your inquiry is an opportune one, for I believe that some of the best men of the engineering profession seriously question whether a young man is not better fitted to take up engineering work as a profession after taking an arts course than as a graduate of an engineering course."

"The college degree means very little to a man in practical life, by which I mean it has little to do with the amount of money he may earn. His compensation as an employee will depend on two things: his ability to deliver the goods and his ability to sell his services. These two abilities are not frequently found in the same man. Many a man has engineering ability far in excess of others who are being paid much higher salaries. Salesmanship is the keynote to the obtaining of high salaries."

"I do not think that a college degree should be a brand of any kind; the fact that he possesses a degree has no bearing on his work in after life."

"The college degree should be a brand indicating the type and abilities of a man, and not a measure of the facts that he may have at his tongue's end."

"Theoretically perhaps, a college degree should be a brand for the type and abilities of a man but practically we know that it is not; and until our system is greatly changed a college engineering degree must refer to a specific amount of special knowledge."

"A.B., B.S., Ph.B. stand for a certain type of man; E.E., M.E., etc., for a specific and special knowledge."

"It brands the type and supposed abilities of a man. The latter is impossible because individuals differ."

"Brand for type and abilities of a man. There is more special knowledge in a $5 handbook than in any degree holder."

"By all means, the type and abilities of a man."

SUMMARY: There is a well-defined majority opinion in favor of making the college degree mean something more than merely a grade of scholarship above a certain minimum. If it mean anything at all, it should denote the more important rather than the less significant characteristics and accomplishments of the man. It is generally known that mere knowledge—scholarship alone—is not the truest index of the value of a man—of the works that he shall accomplish or of the influence that he shall exert upon his fellow-men. As we conceive a broader and higher interpretation of the functions and possibilities of engineering education, so also we shall find means (which must be fair to both the student and the institution) to express this greater significance in the mark or seal of the engineering college.

B. General Policies in Engineering Education

Arrangement, Purpose and Content of Programs and Courses

Question 9. Do you think it advisable to devote the first two years of a college course in engineering entirely to preparation in the theoretical prerequisites, or do you think that the ultimate effect would be better if an attempt were made to devise courses in engineering applications suited to sophomore and freshman students? Would college experience be more valuable with the theory given before the applications, or after the applications, or with the two given coincidentally and in interdependent fashion?

The following typical answers are arranged approximately in order of seniority of those who wrote them:

"Theory and its applications should be given coincidentally from the very start. That this is not more frequently done may be due to lack of adequate laboratory facilities. In some cases this objection may be overcome by working the laboratories overtime. The great danger of the bookish education for the first two years of a college course is that it tends to deaden the powers of observation at the very time of life when they are most susceptible to cultivation, and when it is of the first importance to cultivate them."

"I am opposed to any specialization in the first two years further than is absolutely necessary, and believe that this time should be devoted to acquiring a good foundation in the essentials of language, mathematics, and science. Give the theory before the applications—that is, have the laboratory work follow the classroom work."

"Theoretically and pedagogically it is best to give theory and practice coincidentally and interdependently, as is usually done in the best courses in chemistry. But practically this is impossible, due to lack of funds, equipment, etc."

"Theory and practice should go close together, in some instances one, in others, the other leading. Practice fixes and holds theory, while on the other hand interest strongly aids impressions and nothing so strongly awakens interest as practical experience, even though slight. I think the technical student should have as much practical experience as possible before his course and during his course though not to interfere with same. Vacation periods should be utilized at the suggestion and under the general supervision of the faculty for practice in regular work."

"I think it wise to give a thorough grounding during the early years of a course with possibly one descriptive, not too technical, course upon the subject which the student expects to follow later, the purpose of such course being to put before the student the relation of his theoretical elements to his chosen engineering course, so that the elementary training may not be simply a grind."

"Do not give theory before the applications. Do give them coincidentally, etc."

"Devote the first two years and most of the other two to a thorough grounding in fundamental principles. But let the instructor talk to the students on practical engineering subjects, get them interested in engineering matters, and let them see that they are acquiring knowledge which is useful."

"Give theory and applications coincidentally. Shop work and summer experience should begin at once."

"I do not think it advisable to devote the first two years entirely to preparation in the theoretical prerequisites. The sudent should, however, be subject to more rigid requirements for entrance than were required in the case of my own class (Class of 1892). I believe very strongly that the ultimate effect would be better, were courses to be devised for the freshman and sophomore years so that applications would come hand in hand with theory during those years."

"The engineering course should be completed in two years in outline and should include the mathematics usually taught in four year courses, some physics and chemistry and as much shop, laboratory, field work and drawing as time will permit."

"The chief use of studies of applied engineering is to stimulate interest. Let the student understand that he has to learn the 'how' of practical application in active service."

"It is advisable to confine first two years largely to theoretical prerequisites. But for purposes of rest and development of interest, it is well to have some practical work such as shop, drawing, surveying, electric wiring, etc., taught in the early years."

"Put in a concrete foundation first. Stick to the fundamentals for the first two years—but by means of assemblies, student societies, inspection trips, etc., bring the freshmen and sophomores into intimate contact with men who are doing things, and with technical work in process."

"I believe that theory should occupy the greater part of the student's time. I am of the firm conviction, however, that the application should never be taught before the theory."

"Start freshmen to chaining, running levels, adjusting instruments, designing wood joints and beams and other simple problems. Cut out shop work and lectures on same, and put the student to work, but give him an actual, practical problem."

"I would have theory and practice combined. I do not believe you can give too much of the latter."

"The first two years are awfully dry in most colleges, and while I approve the theory, I am inclined to believe that a youngster would not forget so much of it if he had a few practical applications thrown at him occasionally. He is inclined to lose interest and not keep up his work unless he can occasionally see a streak of light in the darkness. If you can keep up his interest he will perhaps look ahead and possibly study a little once in awhile."

"I was one of but few in my class who had had several years of practical experience between high school and college. I had no difficulty whatever in applying the theory whereas most of the class were objecting to having to take what they were being given and objecting to the amount of work they had to do. I think this reluctance on the part of the student could have been overcome and he could have been greatly interested in the abstruse theory if practical applications could have been pointed out daily in connection with the work. There is still, in most courses, a lot of repetition on purely theoretical work which has very little practical application and is intended mostly for developing the mentality of the student. My idea would be to begin back in the high school with practical applications, as for instance when the pupil is studying geometry."

"Carry the theory and applications along together. For instance, in mathematics and drawing the more simple yet no less practical applications could be applied at once, and in that manner the student would early develop a 'why' for everything which he undertook to do. Later on, more advanced applications could be made."

"The work should be arranged so that the student cannot pass from one thing to another until he has thoroughly mastered the former subject."

"Give theory first by all means, and supplement with enough application to make it stick."

"An engineering student should take subjects allied to engineering in every year of his course.—It makes his aim more real.—Give a subject functionally first, then following with the pure theory which underlies the subject, at the same time reverting back to the application. By this means we proceed from the known to the unknown and the student is not lost nor does he lose interest."

"Problems couched in engineering terms and having to do with engineering materials and machinery would give added zest and would 'cost nothing extra.' Beyond this slight attempt at applications, theory should come first, then applications.—The best practicable arrangement (where time permits, and the course should be lengthened so that it will) would be to have certain interspersed courses which should serve to cause review of the principal courses and in which individual special problems would be served up to the student, causing him to think, to weigh in judgment (perhaps as to relative economy of time or money) and in some sense duplicating the still more real problems of his later career as an engineer."

"The Technische Hochschule of Germany require one year of practical experience before entrance to their courses and there is much to be said in favor of this requirement. It would be highly desirable for our engineering schools to require that at least part of the time of the summer vacation should be spent in practice."

"The first two years of a college course should be devoted to preparation in theoretical prerequisites. I do not believe the course in applied engineering subjects can be made of value to students without more mathematical and scientific preparation. The only thing which is advisable along this line would be a course of lectures by prominent engineers pointing out to the freshmen and sophomores the requirements for success in the engineering profession, urging them to broaden their training as much as possible."

"Based on my own experience, I would most heartily recommend that the theory of engineering should follow the practical application. The student then has some idea of the end he is endeavoring to obtain. Practice will work without theory but theory without practice is almost useless."

"If it were possible to have the actual practice precede the theoretical, the best results would be obtained. . . . . It is a well-known fact that the men who have had a year or more of actual experience get more out of their college course than the men direct from the preparatory school."

"Theory and its applications should be closely connected from the first year of a college course. As far as possible the student's education should be complete in itself as he advances. There is certainly room for engineering schools to improve along this line. One great waste in college education comes from students dropping out of school during the first two years without having acquired any instruction they can use."

"Too often the student attains his Junior or Senior year with no idea of what work he will be called upon to do in his profession and finds that he is unsuited for it or else that it is distasteful to him. I believe that the student should be disillusioned at the start."

"The first two years should be devoted to such studies as English, French or German and Economics, calculated to broaden and round-out the student. Pure mathematics and theoretical principles of engineering should also be covered as fully as possible. The student may learn how to apply these theories to practical problems, in the last two years."

(Note that this man, though graduate in Civil Engineering in 1904, is in the investment banking business.)

"I had a considerable practical experience before I was able to go to college, so my judgment is likely to be warped in that direction. For me it was better to spend all of the first two years on theory, but I do think it would be well to give freshmen and sophomores some work on the application. Theory and practice are not two different things, they are one and the same thing, so I think the theory and the application should go hand in hand as far as possible."

SUMMARY: Of the men whose opinions are quoted above in regard to this question, the oldest was graduated in 1878 in

mechanical engineering and is now the chief engineer of a large western railway; the youngest was graduated in 1905 in electrical engineering and is now the laboratory engineer for a large manufacturing company. Surely the age and experience of such men are ample assurance that they view the matter in proper perspective and are not swayed by pressure of peculiar or immediate necessity. Many of them, if not a majority, remember clearly the chief difficulties and other significant details of their college life, which knowledge should be the basis of an intelligent discussion of the topic in question.

The composite opinion that crystallizes as I study and weigh the individual statements is that the college course in engineering should properly be devoted almost wholly to study of fundamentals—to what are ordinarily construed to be theoretical studies as distinguished from the applied or practical; *but* that for the sake of developing kinetic energy or dynamic interest in the student, the useful applications of this theory should be held constantly in view of the student by the instructor. There is more than enough essential theoretical knowledge which finds use in the ordinary work of engineers, to require a full four years for thorough assimilation of it. There is no time and no necessity to wander, or to try to develop interest, in theory which has only limited or negligible utility except as mere mental discipline. If the instructor would insure pure food for his students by testing every can of theory for its energy equivalent and its digestibility, if not for its palatability, and would discard that which contains too much artificial preservative, he would find all the students coming back for more of the same brand.

Mental discipline is very important, but there is plenty of opportunity for it in useful lines of effort. We may question the propriety of training a young man, who has not earned leisure, to consider golf as appropriate exercise when there is wood waiting to be sawed, and every opportunity for real work in "making hay while the sun shines." As engineers, it is our matured habit not to enter any undertaking which requires the expenditure of time, energy, materials or money unless we can demonstrate the

probability, or at least the possibility of some sort of return, in useful service or in pleasure. We should not be so impolitic and inconsistent as to deny to our students the *evidence,* which their reason demands and their natural enthusiasm responds to, that we are teaching them first of all that knowledge which shall be essential to their success and usefulness in life and which they shall be expected to know. If an instructor cannot demonstrate these things to the satisfaction of even young students who are more tractable and less critical than older ones, it is in the opinion of the writer of this summary to be considered as evidence pointing toward three conclusions: that the material in the course is not well chosen, is irrelevant or "over the heads" of the students, or that the students are not competent to undertake the study and should not have been permitted to do so without the necessary preparation, or that the instructor himself is not competent to teach the subject. We should prepare the student to think as we think in the light of our best knowledge of engineering as a profession—to know a reason for everything that they do, but to do it always thoroughly and well, never superficially.

As one correspondent aptly suggests, every theoretical course many be made practical, interesting, vital and useful if only it be filled with problems which shall engage and develop the powers of the student, and if these problems be made to involve engineering materials and machines, to use the language of the engineer and to instill his ideals, his methods of thinking and of doing. In this sense, every course of drawing, of physics, of mathematics, and even of English, can be made into a real engineering course where students learn to think concretely as well as abstractly, to set up and hold high the ideal and standard of service. When every course is thus imbued with vitality and with the compelling interest which life presents to all men who are alive, the whole curriculum becomes a continuous training in engineering, from the minute the student enters college until he leaves it; all courses are at once theoretical and applied; every classroom and drawing room is also a laboratory, and vice versa: the student has his engineering habits and character established with many times greater

solidity and depth because of the effect of greater repetition of the engineering ideas and associations, greater time in contact with them, and greater number of different angles or points from which to support them.

It would seem to be the majority opinion of those who have an experience broad enough to qualify them to express a valuable opinion, that the kind of course in engineering applications that may properly be given in college does not seriously attempt to render the student adept, nor to show him merely how to produce results by following obediently a given formula or procedure. Rather, the purpose of the "practical" course at college should be to establish the habit to think in orderly and useful fashion and to harmonize each thought and act with certain criteria of thoroughness, of honest regard for truth as it applies, of directness, simplicity and utility. Every theoretical course should be made practical in this regard, that it should develop in the student as much as possible of common sense, of solid values, of powers of observation and analysis, of inspiration, and of healthy respect but not fear for the study itself. If this be done, there remains no cause to discuss whether the course in theory should precede the course in applications or vice versa; they are, in fact, being given coincidentally and in interdependent fashion. They need not then be restricted to any particular period of college experience, nor to any particular subjects or amount of time, because they pervade the entire curriculum. Then the student would not attach odium to theory nor false value to anything that merely sounds practical; and he would not be content merely to pass a course without sensing the revelation and the opportunity of it, nor would he be induced to discard his individuality and become accustomed to docile submission under any leadership that has semblance of scholastic authority.

Question 19. (a) *Do you think that the number of engineering graduates per year is too large for the welfare of the profession?*

Typical answers, arranged in the usual order, are as follows:

"I see no reason to think that the number of engineering graduates is excessive."

"No."

"Not sure. Many are graduated who would be better off in some other profession, and without whom the engineering profession would be better off."

"Never too many good engineers, always too many poor ones. Poor material should be culled out: (a) by high standard of preparation, (b) by maintaining a high standard in college. This very thing was done when I was at Lehigh (1882-1886) and has been developed since. We used to graduate about 50 per cent of entering classes."

"In mining engineering, at the present time, no."

"The large number of engineers out of employment is good proof that the profession is overcrowded."

"Fewer men should be graduated and these should be carefully selected."

"The number of engineering graduates is not too large, nor can they be considered so, except by those actuated by selfish motives."

"With the broadening field of engineering, I do not believe the number of good men graduated each year is too much. The other kind of men will find their own level, whether graduated from an engineering school or a high school."

"I don't think there are too many good engineers but personally I think a man nowadays is foolish to take an engineering course. I say *now* as it seems to me there are other lines which offer greater inducements."

"Students seem to be in good demand. No reason for thinking the profession is crowded."

"Most certainly too many. Quality seems to be lost at expense of quantity. Weeding-out is necessary."

"I believe in having a selected body of students for the work in engineering. I do not mean by this, however, that mathematics shall be the test for all engineers."

"The number of engineering students graduating each year is much larger than the increasing demand for them, but the engineer just graduated is as fit for many other positions as he is for an engineering position, and the natural law of supply and demand will regulate the number remaining in the profession much better than man can do it. Some engineering societies, which are known only among engineers, are vainly attempting to follow the example of labor unions, to exclude from the society all but the elect in order to raise their own financial condition, as it were, by pulling their own bootstraps. Such leading engineers ought to have an extra two-year course in political economy, and at least one semester on the law of supply and demand."

"General engineering has made great strides in the last 25 years and it has been more or less of a fad for young men to study engineering. It would be far better if only a selected body of men who by nature like the study of engineering and are gifted for it, were admitted to college."

"I believe that the number of engineering graduates per year of the type that are being graduated on the average is too large for the welfare of the profession."

"I don't think that the number of engineering graduates per year has anything to do with the welfare of the profession. Those who do not make good do not bother the successful ones."

"The number of engineering graduates per year is perhaps too large but is not the same true in other professions?"

"Probably the number of engineering graduates turned out every year is too large for the best interests of engineering, from a financial standpoint. But this evil is true of nearly every profession and trade and will continue as long as the laboring man and salaried worker are exploited as they are today."

"Yes."

"But if the graduates had been trained more in the general application they would have gotten along better and could readily take up some other line of work than engineering if circumstances necessitated."

"It might be a genuine service if the colleges could swing the would-be engineers off the farms, to the agricultural course instead of engineering."

"Number is too large. Courses should be made more difficult."

"Number is too large, if they all want employment in the same lines and in this country. Specialization will help here."

"Supply and demand will govern."

"It makes little difference how many graduate."

SUMMARY: A fairly accurate digest of the opinions expressed on this topic cannot be made without distinguishing between two viewpoints which already have been quite clearly differentiated

in answers to other questions of this series. Broadly conceived, the college course in engineering is a preparation for life and activity in any sphere, but in harmony with natural laws and economic principles. Rather narrowly conceived, it is an intensive study of science in preparation for the practice of a particular profession or specialized use of science in business.

Thus, in the first instance, we find graduates of engineering colleges making good use of their engineering training as merchants, executives, manufacturers, patent lawyers and farmers. I personally know several men who sent their sons through engineering courses in college with no expectation that the young men would make of engineering a profession or a livelihood. They merely believed that engineering was the most direct and useful study of truth, of sound principles and of clear, direct, incisive methods of thinking, and that it would be the best preparation to solve the problems to be met in any phase of life or of business. In this view, the field for college-bred engineers is not in a particular profession or specialty within a profession, but is in *every place* where brains, usefully applied, can achieve results. Therefore, we should not gauge opportunity by the degree of saturation within the profession or any branch of it. Lack of opportunity in the specialty does not indicate that it is bad judgment to study engineering, but rather that the engineer should find more fields for the application of his methods, such as the fields of administration, of finance or of general business, where unprecedented success may await the search for truth, for simplicity and efficiency which the engineer is habituated to pursue.

According to the narrower conception, the engineer may concern himself only with the science of materials and natural forces, of structures and machines; when activity slackens at dictation of finance or business in which the engineer has grasped no part and seeks no control, or when young men put themselves through training faster than jobs can be supplied, we are compelled in this view to accept it as evidence that the profession is crowded and that this is a good reason to attempt control of the number of students.

It would be to the advantage of society as well as of the engineers themselves, if the former viewpoint were generally adopted. There is some evidence to show that it may be so adopted when engineers broaden their own interests and become alive to opportunities which are all about them. From the discussion submitted, I receive the impression that the majority of Tau Beta Pi men take the broader view and see the larger opportunity; that the number of engineering graduates is not and cannot be too large for the welfare of the good engineers or of the engineering profession or of the world, although it may be too great for the best financial interests of the mediocre or poor engineers. However, no harm, but real service, may be done such men by conditions which force them to try their abilities along other lines.

Question 19. (b) *Would you favor a change of policy in the schools to the end of teaching engineering to only a selected body of men—those who really want to study engineering—instead of accepting large numbers that apply for instruction, many of whom are a drag to the others, a trouble to the teachers, and if graduated, anything but a credit to the profession?*

"Even a dull student is benefited by his college training and is raised to a somewhat higher level."

"Yes. Considerable effort should be made to admit only those students who seem to be born engineers. But there is considerable difficulty in discovering who these are, with our present standards of admission."

"Yes, by a selected few institutions who can get and pay the corresponding quality of teachers."

"Effort should be made to discourage a number of those who now take engineering, as they evidently are not adapted to the work. A strengthening of the theoretical training and laying less stress upon the practical money-making studies would be the best way to limit the number of engineers."

"It is probable that the demand for young engineers in the next fifteen years will not be as great as in the past fifteen years, for the reason that the product of the past fifteen years will be the men of affairs for some years to come. . . . . Therefore I believe that the faculties of engineering colleges should do a little 'pruning' in the first year, and if there be any who give promise in other directions, they should be guided to their proper vocations."

"I often think of what President Clute of the Michigan Agricultural College told me when I entered that institution. I was feeling very nervous over the entrance examination, and he said to me: 'This examination is to get men into college, not to keep them out.' The substance of his remark should be the keynote, the governing principle of every institution of learning."

"Yes. Limit to those who really want to study engineering."

"*Every* applicant for admission to a technical college should be obliged to pass an *examination* covering 'the three R's' and all other primary subjects. No certificates from any schools should be accepted. It is important to discover what an applicant *knows*, not what he has studied. This provision would prevent entrance to college of many a young man who is totally lacking in the fundamentals. The public school of today is far less efficient than the one of twenty years ago. Their graduates have a mass of superficial knowledge but are not thoroughly grounded in the essentials and have not been taught to study. These essentials are not taught in a college and cannot be. Hence many a college graduate is ignorant of the primary subjects. He can neither write nor spell correctly, and is incapable of writing a simple business letter."

"Restrict the graduates to those who show real aptitude for the work."

"A process of selection and elimination might well be attempted by the engineering schools. Many boys enter the courses with little knowledge of what they are undertaking and less taste for the work."

"I am in favor of restricting the number of students taking engineering courses just as soon as the states wake up to their duty and establish trade schools. There are at present many graduates of engineering schools who are filling positions which are well within the capabilities of a trade school graduate. Whenever the Land Grant Colleges get back to the idea that they should be trade schools the engineering colleges can put up their entrance requirements so as automatically to limit the number of persons studying to be engineers."

"After the sophomore year, would begin to weed out the students, kindly suggesting to those who are not adapted to technical work that they could very probably find more promising openings in other lines of endeavor. A faculty should not graduate a man whom they cannot recommend but it is oftentimes done."

"I do not think that any practical means could be established of limiting the number of students. We must, in common with all commodities, submit ourselves to the law of supply and demand. By raising the standard of entrance condition, the standard of the graduate will be raised and therefore the number tend to be limited. This seems to be, to me, the only solution of this question."

"I think the engineering profession would profit by general adoption of rigid requirements and the culling out of those men who cannot make good. This is a selfish view however. The greatest good to the greatest number probably means a contrary policy."

"It would seem to me that an ideal condition would be reached if tests could be arranged so that the men entering college could be classified according to their natural endowments, their previous preparation and their natural bent, taking into consideration their financial resources and prospects, their moral and mental tendencies and equipment and their physical condition so that the college would not try to make an all-round engineer of a man fitted only to labor in any profession or employment, they would not try to make an executive of a man without initiative or creative ability, but would develop inventive and creative tendencies where they exist, strengthen rudimentary faculties, and all with an eye to the possibilities in the man.

"From observations of the men in my own class I believe that the majority go to college at too early an age. They have too little stability of character, they lack a serious attitude towards life, they have never come in contact with enough practical affairs to know how to apply theory that is given them; they have very crude ideas of the value of a dollar and how to obtain one. Those in my class who came to college later in life, some of them six or seven years older than the average, who had had practical experience, who had earned their own living, did better work without exception. They knew how to apply what was given them, they looked upon their work seriously, they spent more of their outside time in observation and reading and at graduation were much further advanced towards success than those who came to the course at a younger age. Aside from this there were many in the class who would never make engineers if they went to college from ten to twenty years, but this did not prevent some of these men from making brilliant successes after they left college, when, by good fortune or otherwise, they were shifted into places not requiring engineering ability but requiring other qualifications such as inventive ability, management, systematizing or even plain supervision of common laborers."

"The writer is inclined to believe that it is a fact that a very low percentage of college graduates in the engineering courses ever take up what might be considered genuine engineering work. It is also probably true that the larger percentage who do not follow the lines of study in their after life work are more or less of a disappointment to themselves and to their friends. Primarily, it is probable that the cause for this trouble is twofold: First, a mistaken notion on the part of parents and friends that an interest in mechanics and a love of things that go round are an indication of a bent for engineering work; and second, on the part of our colleges and universities where engineering schools have been established to meet this demand, an offering of courses of technical training without requiring suitable general attainment before the would-be engineering student matriculates."

"The writer was much impressed by a remark recently made to him by an official in one of our local Steel Corporations, who in speaking of the apprenticeship course schools that these companies are introducing into the regular shop system, said that it was getting to be more and more apparent that 'the average American boy is unfit for the position higher up.' This remark was applied, of course, only to those who have obtained a common school education; it applies also, however, to a very large percentage of our technical college graduates, and

the writer believes that more attention paid to those things which develop moral character would be of the greatest benefit to the engineering profession and to the schools that are aspiring to have their graduates excel in this line of work."

"I would apply the Wirt system to all those that are desirable. Here there are no definite classes or grades to which an entire body of students is transferred at definite times each year, but students are individually advanced from one grade to another as they are ready for advancement. In that manner, those who work and have capacity are not held back by others."

"I would not favor a policy to curtail the number of students, but I would raise the entrance requirements and make it harder work to finish the course. As an employer I find it hard to get young men that can adapt themselves to conditions. Engineers as a rule get so wrapped up in the details of their work that they lose the proper perspective view. They do not let their light shine; they do not toot their own horn enough for their own good."

"Universities should not spend time and money to train men who are fit for nothing but drafting."

"A great many of the engineering graduates drop out of engineering after graduating. Because a man is no good as an engineer does not discredit the school or the profession. If he takes an engineering course and graduates the chances are he can make a respectable living and otherwise perhaps he couldn't. A good man will make good anywhere even without an education but the man of poor quality who would be a drag on society without the college course may be made a good member of society if he can get through."

"Too many men are accepted and trained in lines where they cannot possibly succeed."

"A two-year preliminary course would be valuable to many, and another two-year advanced course for those who wish to specialize further."

"There should be no more of this advertising and urging to encourage the enrollment of new students. There are too many graduates being poured out each year who are of a mediocre sort or are even positively worthless and do much injury to the profession at large. Students should not be accepted unless they have the necessary physical and mental capacity, a well-defined desire to become an engineer, and a substantial training in fundamentals. If these matters are not fully determined at entrance time, the careful wide-awake instructor will soon be able to 'spot them' and the deficient ones should be dropped at once and forever for the sake of their own future happiness and welfare of the college and the profession."

"The entrance requirements might well be raised to include higher algebra, plain and spherical trigonometry and a slight reading knowledge of one or more foreign languages. The principal advantage would be obtained, however, by *requiring a high degree of excellence* in the subjects that are used for entrance. This would be a much more satisfactory method than simply increasing the number of subjects."

"It often happens that students who were thought to be only mediocre while in school, have far more practical success than the brilliant students, and I believe that any method of advance selection which would be adopted would result in the elimination of many good men."

"A public educational institution owes as much opportunity for development to one type of mind as to another, and this can be accomplished more successfully than it has been done by dividing students into smaller classes, being careful to group similar types together, and not requiring castiron standards of attainment. I favor teaching engineering not to *a* selected body of men but to *selected bodies* of men."

"If all that graduated in engineering followed it, the profession would indeed be overcrowded but we know this is not the case. A general engineering education is beneficial to anyone no matter what line of work he may afterwards follow, much more so in my opinion than the ordinary college course leading to an A.B. degree which fits a young man for anything but work. True we would be able to do better work if we could weed out those men who *we* think will not be successful engineers, but this weeding process would no doubt throw out many a good man who afterwards would be highly successful and also it would deprive others of an education that would be of benefit to them in whatever line of work they might choose to enter."

"There is a great deal of room for improvement in the ideals of undergraduates and the attitude with which they regard their work."

"If it were possible to do so, I believe we could have better students by requiring two years of actual, practical work in the office or field before entering the University. Two weeks of the pay envelope raise havoc with the average man's intentions as to studies and college. I know many men myself included, who would have gotten more out of their work at school if they had known what they were doing."

"Yes, but see no practicable remedy; time levels these matters to a considerable extent. . . . . Probably all of us who have been engaged in practical work for some years know personally of such cases as make us doubt seriously the ability of any faculty committee to pick out the dead timber and leave the promising ones to continue along the pathway to success.

When I was in college there was a general feeling among my fellow students (I include myself) that the designing engineer was the only true engineer, that the operating engineer and the erecting engineer were on the lower rungs of the ladder, and that the sales-engineer had so prostituted his opportunities that he was unworthy of the latter part of his self-chosen title. These ideas were undoubtedly imbibed from the general layout of our curriculum and the attitude of the faculty as regards unconcealed distaste for commercialism. Now I am inclined to look upon the small army of designers as largely sublimated clerks, taking orders from the commercial field which has drawn the men having initiative and push regardless of scholastic attainments. Generally the world is right; how then is anyone to eliminate the unfit by choosing on a scholarship basis and before the test of workaday life has come?"

"Dead timber *cannot* be carried through any *well-regulated* school. Most of it is eliminated in the first year."

"Entrance requirements should be fixed so that a man could not enter until he had reached an age when he could think and reason rather than memorize. The student of mature age or who really wants to study engineering is the one for whom the course of studies should be adapted. The men who graduate then would not have to accept positions of as low grade as many do at the present time, especially if they had had, prior to entering college, a considerable amount of practical experience, which would be quite likely if they entered at a mature age."

"Requirements for entrance should be more strict on fundamental lines. Regular work should be watched more carefully, thus weeding out those who are not workers and who are at school for a good time. The world should feel that a graduate of a technical school should be a man with definite qualifications and in hiring such a man they would get good high-quality material."

"Yes. Main trouble is in the administration of the schools—the teaching profession itself. This condition is brought about by popular sentiment."

"Yes. A requirement of practical work previous to Junior year would show to many their unfitness for the profession."

SUMMARY: The answers to this question were generally full and interesting, and have been quoted very generously. The prevailing opinion seems to be that means should be devised to guide away from engineering and toward more appropriate fields those men who do not demonstrate that they possess the interest and abilities which make engineering work congenial and give promise of a degree of success and satisfaction commensurate with the expenditure of time, energy, opportunity and money that will be demanded in preparation. This guidance is not generally thought to be necessary for the good of the profession, however, but only for the good of the aspirants themselves. It is also for the good of the college and of the community, in that better adaptation of the course of training to the possiblities in the individual student should result in less economic waste of the resources of the college, with consequently higher development of the more able men and more general help to the less able masses for the given amount of funds, time, energy and material which are available for education.

It is not considered impossible to operate schools, including engineering colleges, in a way to accomplish the greatest good to the most able individuals as well as the greatest good to the greatest number, if the system of instruction be less standardized and more flexible or adjustable to the natural varieties of real human beings for whom it is supposed to be designed. Various suggestions are made in this direction, including *vocational guidance* for intending students, or expert advice based on analysis of character and temperament and on a wide knowledge of the requirements of professions, business, and trades; *requiring for entrance* to the engineering college greater *maturity* and *practical* industrial or commercial *experience* in the individual prospective student; rearrangement of curricula so that students of small endowments and limited prospects may drop out of school *after having received full value for the time and effort already expended,* whenever the further prospect becomes uninviting; reform of the grading system so that *each student shall be advanced as fast as his individual accomplishments warrant,* regardless of the progress of other students; and above all, *sympathetic interest and effort of the teacher* for each student, and restriction in the size of classes as far as funds will permit, so that this interest may be effective.

The conviction seems to be quite general that the raising of entrance requirements for engineering colleges would be the most effective means of locating the men who have prospects of becoming good engineers, and avoiding the economic waste and the disappointment due to misfits and illusions, *provided* that a method of examinations be devised or employed which shall distinguish wilful purpose from mere interest, fine grain from high polish, character and ability from accomplishments. From such an examination no individual or class should be exempt; everyone should demonstrate that he is fit *now,* and everyone stand fairly on his own merits. No one should be improperly confused by prospect of examination if our practice were to make examinations usual instead of rare and if the examinations were fair to all sides of the man.

In the opinion of the writer of this summary, we should not draw a conclusion in this matter without considering the most important benefits of college life and of scientific study as discussed already in response to questions number 2 and 3. To many people the value of a college course has little or no relation to the later opportunities and achievements that may be due to it. The value comes rather in the increased pleasure of living; in the vastly increased interest and significance of things and of men; in the power to think, to concentrate, to conceive ideas and to take them apart or put them together; in short, the value comes in knowing more paths to happiness and contentment through wider cultivation of the tastes and sensibilities. This being the case, it rests entirely with the individual how much additional value or return he may expect, in the nature of professional reputation or fame, or money.

Question 16. In about what proportion should the engineering students' time be divided among the following general divisions of study?

A—Mathematics.
B—Chemistry.
C—Physics.
D—English.
E—Foreign languages.
F—Drawing.
G—Shopwork.
H—General mechanics, suitable for all engineers.
I—Special engineering studies in lines the student thinks he would prefer to follow.
J—Business, accounting, law, economics, and other related subjects.
K—Purely cultural subjects, as history, music, art, etc.

Wherever the answers have been given in such form as to permit, they have been included in the accompanying tabular report; otherwise they are to be found in the statements below. In each case, the order is approximately that of seniority.

"Business, Accounting, Law, Economics, and other related subjects taken together, is a large order. It would be preferable to confine the attention, at least at first, to Accounting. The great trouble seems to be to get the average engineering student interested in such matters. This interest might be aroused by quoting George Stephenson's saying, 'The highest form of engineering is the engineering of men,' and then remarking that such engineering requires a good general knowledge of the above-named subjects and that General and Cost Accounting may well be learned in the college course. With regard to cultural subjects, a recent article in the *Outlook*, written by an academic graduate, expresses regret that in his case too much time had been spent on Latin and Greek. As a cultural subject he prefers geology, on account of its broadening influence."

TABLE I

A	B	C	D	E	F	G	H	I	J	K	REMARKS
Mathematics	Chemistry	Physics	English	Foreign Languages	Drawing	Shopwork	Genl. Engineering Mechanics	Specialized Engineering Studies	Business, Law, Economics, etc.	Purely Cultural subjects	Please note that these are relative numbers, but not always percentages.
15.0	4.5	9.0	7.5	0.	9–12	2–3	–15.	18–20	3–4	3–4	12–15% of special engineering studies in lines other than student intends to follow.
15.	5.	5.	5.	5.	5.	10.	10.	32.5	2.5	5.	
10.	?	5.	5.	*	10.	5.	10.	10.	2.	*0.	*Elective. C. E. Course.
15.	5.	10.	5.	0.	5.	5.	10.	30.	10.	5.	
*40	2.	5.	2.	0.	10.	0.	10.	10.	5.	5.	*Including application of the mathematics.
20.	5.	5.	10.	0.	8.	10.	20.	2.	20.	0.	
16.	6.	6.	*0.	0.	24.	8.	9.	?	4.	10.	*Entrance requirements in English should be raised, except for foreign students.
25.	9.9	9.9	5.9	7.9	4.0	29.7	*—	?	7.9	0.	*Included in A, with mathematics. Schedule for M.E. Course.
10.	10.	10.	5.	10.	5.	10.	15.	5.	10.	10.	
12.	12.	20.	4–6	0.	10.	12–15	16–18	25.	5.	*0.	On basis of credit hours. Total number of hours in course 116 to 123. *Elective.
12.	6.	8.	4.	6.	5.	10.	*	*	4.	3.	**Together, 42%.
10.	*15.	8.	5.	3.	6.	3.	8.	40.	2.	0.	*This is for course in Mining Engineering.
10.	5.	5.	0.	0.	10.	10.	10.	40.	10.	0.	
15.	3.	8.	7.	0.	17.	15.	10.	15.	8.	2.	
12.	8.	10.	8.	8.	8.	8.	12.	8.	13.	5.	
15.	5.	10.	10.	5.	5.	5.	5.	15.	15.	10.	
18.	11.	5.	3.	0.	8.	5.	12.	33.	5.	0.	
20.	10.	10.	5.	0.	10.	5.	15.	10.	10.	*5.	*Ethics.
15.	5.	10.	10.	0.	5.	0.	25.	10.	10.	10.	
*	*	*	*	0.	*	0.	*	*	*	0.	*Course as at Stevens Institute, except the studies which are marked 0.
11.	4.	6.	12.	5.	6.	3.	12.	25.	6.	*10.	*Should include logic, astronomy, and geology.
10.	10.	10.	10.	0.	5.	15.	5.	15.	10.	10.	
20.	5.	5.	5.	1.	10.	20.	10.	20.	2.	2.	
15.	10.	15.	10.	0.	2.	2.	20.	21.	10.	5.	
15.	5.	10.	10.	0.	5.	0.	25.	10.	10.	10.	
20.	10.	10.	5.	0.	10.	5.	15.	10.	10.	*5.	*Ethics.
20.	5.	8.	5.	*0.	16.	16.	10.	8.	6.	6.	*Elective.
15.	*—	5.	5.	*—	5.	5.	10.	30.	10.	*—	*Remaining 15% distributed as student desires.

TABLE I (*Continued*)

10.	10.	10.	10.	5.	2.	2.	10.	33.	3.	5.	
13.	8.	8.	6.	0.	3.	9.	17.	20.	6.	10.	
10.	3.	6.	6.	*—	10.	10.	10.	15.	15.	10.	*Optional.
20.	15.	16.	20.	5.	8.	4.	12.	60.	13.	*4.	*Or more.
15.	10.	15.	10.	5.	5.	0.	15.	10.	10.	5.	
10.	5.	5.	3.	0.	10.	10.	15.	40.	2.	0.	
12.	5.	13.	*1.	7.	14.	9.	13.	20.	5.	*1.	*Questionable.
12.	7.	7.	6.	6.	11.	3.	10.	27.	5.	5.	
20.	5.	10.	5.	0.	5.	10.	15.	15.	5.	10.	
20.	10.	5.	10.	0.	5.	10.	15.	10.	10.	5.	
12.	8.	8.	4.	5.	3.	3.	10.	30.	12.	5.	
10.	3.	5.	7.	10.	10.	0.	5.	30.	20.	0.	
12–15	7.	7.	2–3	7.	7–9	4–6	25.	25–27	2.	0.	
15.	5.	5.	5.	10.	5.	0.	15.	20.	10.	*10.	*Including psychology.
20.	15.	5.	*—	*—	3.	*—	2.	45.	2.	1.	*Variable.
15.	7.	7.	4.	4.	10.	4.	20.	20.	5.	4.	
20.	10.	10.	10.	0.	6.	5.	5.	70.	15.	9.	
6.	4.	4.	1.	0.	4.	2.	5.	3.	1.	0.	
20.	5.	5.	20.	0.	10.	*0.	10.	20.	5.	5.	*For the Civil Engineering Student.

"It took an assistant two months and me two weeks and much cash to answer this question for mechanical engineering students alone. See Proc. S. P. E. E., 1908 or 1909."

"A study of the four engineering courses at this institution shows a pretty consistent average in the distribution of hours between letters, science, general engineering and special engineering studies. The average for the four schools for the entire four years is 15% for letters, 40% for science, and 45% for engineering studies of which about 20% is general and 25% is special technical work. In the progression from the freshman to the senior year, there is a gradual decrease in letters and science and a corresponding increase in engineering work, special engineering being confined largely to the junior and senior years. Under your classification, D, E, and K would come under letters; A, B, and C under science. F, G, and H under general engineering; and I and J under special engineering."

"I do not feel qualified to go into details, but strongly recommend the subjects listed under D, J, and K."

"D should be had before entering. K should not be part of an engineering course; should be used as recreation if necessary. J should be included in senior year at least."

"It is difficult to devise a specific answer to this question; so much depends on the length of time a student remains in college. With his earliest usefulness in view I would suggest this arrangement of subjects in order of their importance: Mathematics, Shopwork, Drawing, Laboratory, Special Engineering Studies, Chemistry, Physics, English, Foreign Language, General Mechanics, Business, Accounting, etc., Cultural Subjects. I place special engineering subjects before physics, chemistry and mechanics because textbooks may be obtained which contain in themselves the essentials of the last named subjects. Numerous works on machine design, steam, oil, and gas engines, refrigeration, etc., contain so much of physics, chemistry and mechanics that special study of these subjects is hardly necessary except as a finish."

"The 'Throop idea' is to devote 25% of a student's time to 'science'—mathematics, physics, chemistry; 25% of time to 'culture'—languages, economics, history and English; 25% of the course to 'technique'—shopwork, drawing, and laboratory; and finally, 25% of the total course to 'engineering'—design, problems, and thesis."

"A freshman should be taught to read a vernier, run a line of levels, chain accurately, adjust instruments, figure yardage and all such simple problems which occur constantly in practical work; any high school boy has enough education to do this. Sophomore students of civil engineering should know how to design beams, simple roof trusses, joints, girders, and do it rapidly. . . . . Field work should be finished. Juniors should design complete truss arch, wall and dam, and stick at it every afternoon to the exclusion of other things."

"Culture is not obtained by smearing on subjects, it is an attitude of the mind and an appreciation of that which is good in the wide variety of interests. It can best be obtained by contact with the proper personalities. Culture is not obtained by forcing one to read certain literature to get a college credit but it is fostered when one reads this same literature (if it is of the best) for its own sake and when one finds enjoyment in doing so. It is not obtained in analyzing the anatomy of a book but in living the thought of a great author."

"Cultural subjects, English, and foreign languages should be cut out entirely. Something in the way of business accounting and law may be offered if time can be spared."

"I have always felt that one of the defects of a technical education was neglect of the social side of college life. The hours are so long and the curriculum demands so much, that scant time is left for the making of real friends amongst the other students. And experience, no less than observation, has shown me how valuable, from a purely materialistic point of view, such friends may be and usually are, in the advancement of one's career."

"I would not attempt to make any divisions of studies. The one thing I would suggest would be that the courses would be better if English were continued throughout the course, and that a few economic studies be added."

"A man makes his own position and if he is in one place long enough it is likely that he will develop his position to the point where he uses all that he knows. For this reason it is difficult to determine what should and what should not be taught in an engineering course. Anything that develops the ability to think in terms of spatial relations is a part of engineering education not wasted."

"I have not allowed any time for English, Foreign Languages or Cultural Subjects. I think that the use of good English could be taught with order subjects. Foreign languages are a waste of time unless the student really desires them. In regard to cultural subjects, there are usually literary societies or organizations of that nature which may supply this part of the education. Mathematics is not very useful except it enables the student to understand mechanics and physics and serves to train the mind for clear thinking and reasoning."

"I could not attempt to give a workable outline of proportions for the various branches of study. I believe, however, that the laws of *business* and *economics* should be given greater emphasis in engineering courses."

"Subjects A to H, inclusive, should be covered in the first two years."

"These are some of the courses that I consider specially valuable to civil engineers: Economics of engineering, corporation accounting, law of contracts, business law, engineering jurisprudence, elementary philosophy, logic, ethics, and social psychology."

"Depends upon the likes and dislikes of the student."

"Omit English (as formal study) and shopwork. Omit also all cultural subjects."

"I am *certain* that business, accounting, law, economics, etc., should be included to a much greater extent."

"I do not believe much in special engineering subjects, considering the age and previous experience of students; especially since these subjects are the most expensive ones for the schools, which are too generally poor, to furnish."

"Drop out E (foreign languages). K (cultural subjects) is better obtained outside of college."

"Mathematics (culminating in a really good, not memory, course in mechanics); English all four years. Physics is not sufficiently emphasized in the engineering courses. Business might be given outside of regular hours."

"I object to the term 'culture subjects,' as I think pretty much all of the subjects taught are cultural; but recognizing what you include under this head, I should omit it and include certain general science such as metallurgy, geology, mineralogy, botany, etc."

SUMMARY: The feasibility of this part of the questionnaire, and the significance and value of the answers made to it, depend upon the scope and functions which we assign to the ordinary college course in engineering. The question was founded originally on my personal conviction that the four-year course, of necessity, could not be concerned with anything beyond the fundamental essentials of engineering training, which are practically the same for all branches of engineering. The answers to other questions previously discussed have supported amply this viewpoint; consequently, it is permissible in this summary to strike an average between all the answers, regardless whether they come from civil engineers, mechanical, electrical, or chemical engineers, or any other professionals in applied science. Within Group I (Specialized Engineering Studies), and without affecting its relations to any other group, we may make such slight differentiation between the various branches as may be proper (in college training).

All answers, in which proportions of the various divisions of study were stated in numbers, have been grouped in Table I. Here the figures are given just as they were stated by the respondent. To reduce all figures to a definite common basis for discussion, I have in all cases given to mathematics a weight of 1.0, and have reduced all other figures of each respondent in the same proportion as mathematics. While we may not all agree as to the total amount of work or the number and variety of studies that should make up an engineering course, we are all fairly well agreed

that mathematics is distinctly and peculiarly fundamental to engineering, that mathematics is not likely to be confused with other studies, and that a fairly definite and uniform mathematical training is requisite to all branches of engineering. Taking the amount of mathematics as a unit, Table I may be summarized as follows:

TABLE II. SUMMARY OF TABLE I
Based on Mathematics as Unity

	Subject of Study	Max.	Average	Min.
A	Mathematics	1.000	1.000	1.000
B	Chemistry	1.500	0.518	0.050
C	Physics	1.670	0.599	0.120
D	English	1.090	0.460	0.000
E	Foreign languages	1.000	0.214	0.000
F	Drawing	1.500	0.555	0.130
G	Shopwork	2.380	0.504	0.000
H	General engineering mechanics	1.850	0.893	0.100
I	Specialized engineering studies	4.000	1.580	0.100
J	Business, law, economics, and related subjects	2.000	0.555	0.100
K	Purely cultural subjects	1.000	0.328	0.000

The total of the averages in Table II is 6.951. If we decide, on this basis, that the entire course in engineering should require an amount of work equivalent to 6.951 times that which is devoted to mathematics alone, and if we recalculate the time allotted to each division of studies on the basis of 100% for the entire engineering course, we finally arrive at the values in Table III:

TABLE III. SUMMARY OF TABLE I
Average figures only, on basis of 100 per cent for total time devoted to entire engineering course

	Subject of Study	Percentage Average
A	Mathematics	13.9
B	Chemistry	7.2
C	Physics	8.3
D	English	6.4
E	Foreign languages	3.0
F	Drawing	7.7
G	Shopwork	7.0
H	General engineering mechanics	12.4
I	Specialized engineering studies	21.9
J	Business, law, economics, and related subjects	7.7
K	Purely cultural subjects	4.5
	Total	100.0

The figures and opinions upon which this average apportionment of hours is based, are fairly representative of the engineering profession. They come from men who studied at a relatively large number of engineering colleges in all parts of the country, from men who were graduated as early as 1878 and as late as 1911 in all branches of engineering, from men who are or have been engaged in professional practise of engineering or in diverse lines of business or in teaching, with varying degrees of success. We see the effects of these differences in the wide range between maximum, minimum, and average values in Table II.

There is apparently a fair degree of agreement regarding the proportion of time to be allotted to certain studies. Thus, twenty-five out of forty-six respondents represented in the tabular report (or 54.3 per cent) voted that no foreign language work whatever should be required in a four-year engineering course. The weight of the remaining 45.7 per cent of the voters represented is only enough to indicate that, on the average, the time allotted to foreign languages should be not more than 21.4 per cent of that devoted to mathematics, or 3.0 per cent of the total time devoted to the entire engineering course, or less than half that which should be devoted to the study of the English language. Eleven out of the forty-six voters represented in the tables, or 24 per cent, were of the opinion that purely cultural studies should have absolutely no place in an engineering curriculum, the average opinion being that the amount of time devoted to them should not altogether exceed 33 per cent of that devoted to mathematics, or 4.5 per cent of the total time devoted to the entire engineering course.

Summarizing all opinions, presented tabularly and otherwise, and having regard for repetitions not represented, we are led to believe that alumni quite generally are in favor of abolishing from the curriculum the study of foreign languages, and of increasing the amount of time devoted to subjects that familiarize the student with principles governing the ordinary business activities in which he must engage after leaving college. They are quite generally agreed that the student should receive more training in the use of the English language, as a useful instrument for unequivocal ex-

pression, if not to develop greater elegance of personal address or taste and appreciation for good literature. Their opinion is divided, however, whether this further training should be a part of the regular engineering course, or should be prerequisite or outside of it.

Furthermore, there seems to be prevalent an opinion that shopwork should receive somewhat less emphasis than was in general formerly considered necessary or proper. In view of the enormous recent improvements and present rapid advance in shop methods, this trend of opinion is rather interesting. As it undoubtedly does not indicate that manufacturing offers no field for college-bred engineers, it probably does indicate that the colleges do not or cannot give the proper kind of instruction in shopwork. There seems also to be a tendency toward reduction of the time devoted to specialized engineering studies, and toward increasing the time devoted to the general mechanics underlying all branches of engineering. This reiterates the objection to specialization and the emphasis upon common fundamentals, which have been brought out in previous discussions.

Question 17. If it be impossible, in the time available, to give all things that seem desirable, which, in your opinion, can be sacrificed with least injury to the student?

Typical answers, arranged in approximate order of seniority of the writers, are as follows:

"To get the most complete all-around training in the limited time of these shorter courses, it might be well for many students to omit the time-honored thesis."

"Academic subjects, which should have been taken in a preliminary course. I have asked this question of many men. They all can tell of *additional* subjects which should be taught, but not of subtractional subjects."

"If anything is to be sacrificed, I think it should be the special technical studies rather than those of a more general character."

"In a four-year course, sacrifice 'cultural' subjects. I would include in this foreign languages."

"Depends on the course. For instance, drawing, shopwork and mechanics could be sacrificed by the chemist, while chemistry might be sacrified by the mechanical engineer."

"If anything must be sacrificed, I would suggest the following order: Shopwork, cultural subjects, business and law, foreign languages."

"Leave off the upper stories of so-called practical engineering, that look so well on the plan; but don't sacrifice the foundations. Don't keep a boy working four weeks on a design of a plate girder that would be turned out in one day in a drafting room; but *do* ground him in the theory of stresses."

"I consider the following in order of importance: A, C, F, G, E, B, H, I."

"Foreign languages, shopwork, special engineering studies."

"Special lines might best be sacrificed."

"I would sacrifice cultural subjects, and detailed applications under I."

"Cut the 'superstructure' in favor of the 'substructure.' School is the place to put in the concrete foundations and not to build showy frills."

"Cut out foreign languages and business, accounting, law, economics. Student can acquire these after graduation."

"If things that are primarily preparatory school work are *demanded* of these institutions, and the fancy courses cut out of the technical schools, I believe a very good fundamental course can be given in college."

"Special engineering studies, and cultural subjects, with the exception of English, can be eliminated."

"If any had to be eliminated, I would cut them out in this order: Shopwork, drawing, business and related subjects, part of general mechanics."

"Rather sacrifice the special subjects."

"English and chemistry could best be sacrificed, in the order named."

"It would, however, be quite possible to have some of the shop credit obtained by work during the summer and it might be very desirable, also, to have some of the work in English depend upon reading and preparation of reports or essays which would be a requirement for reëntrance in the succeeding year."

"All descriptive subjects should be first sacrificed to give place to fundamental theory and to culture subjects."

"The most technical."

"The special engineering studies must of course be sacrificed."

"Sacrifice advanced parts of mathematics and mechanics, history, languages, music and art (excepting architecture)."

"Foreign languages should be omitted, to be gotten elsewhere if desirable. Mathematics courses could be consolidated."

"I know a young man who could not finance the whole course at Columbia University, but he finished two years creditably, getting his mathematics, physics, etc., and learning how to get his knowledge from books. Now he seems to be getting along as well as if he had been graduated. He studied a book on alternating currents I loaned him, and soon came around and bothered me with questions I could not answer, as well as running down some errors in the text. The moral of which seemed to be that, once a student has the groundwork or foundations, it does not make much difference what other part is sacrificed."

"I would simply state here that I remember nothing of *German* or *Chemistry*. On the other hand many *may* have happened into positions in which those subjects, amplified of course, were of great importance."

"If the aim is to turn out an ordinary, practical, unpolished engineer the subjects least needed will be: Chemistry, Modern languages, appraisals, accounting, business law, cultural subjects."

"I would sacrifice music and art."

"Sacrifice cultural subjects, foreign languages, English."

"Eliminate 'cultural subjects' and condense D, J, E, G."

"Calculus, advanced chemistry, foreign languages, and drawing should be eliminated, so that more time could be spent on engineering subjects."

"Shopwork and foreign languages."

"Sacrifice the languages."

"Omit English, shopwork, and cultural subjects."

"Eliminate shopwork in college, and replace it by shopwork before or after college."

"Sacrifice foreign languages and cultural subjects."

"Foreign languages, shopwork, and then cultural subjects."

"German or other foreign languages."

"Foreign languages and shopwork."

"Omit special engineering subjects, as usually taught. Have a good general course."

"Foreign languages and shopwork."

SUMMARY: The trend of opinion upon the subject of this question should be so fairly evident from the answers quoted, that little is necessary in the way of a summary; especially so, in view of the discussion upon the previous question. The order in which studies should be sacrificed for lack of time, seems to be about as

follows: Foreign languages, shopwork, special engineering subjects (applied engineering or practical courses), purely cultural studies, English, advanced parts of mathematics, chemistry, drawing. The belief seems practically unanimous that foreign languages should be first to go by the board. A few plead in favor of languages, but they are usually people who have been cast into positions where knowledge of languages, or of a particular foreign language, is an immediate necessity or has a peculiar value. There seems to be here no advocates of the contention that foreign languages are valuable as purely cultural studies.

Before any subject of study is eliminated from the curriculum for lack of time, it should be the duty of teachers to study the efficiency of their own machinery and its work; and it should be the duty of the administrative officers of the staff to see that the teachers do this. As long as necessary courses contain accumulated dead material or are presented in spiritless or laggardly fashion, as long as there is lack of coöperation and correlation between courses resulting in unnecessary repetitions, there should be no thought of completely excising any desirable course from the curriculum.

Question 18. What do you think of five-year and six-year engineering courses?

Typical answers, arranged approximately in order of seniority of those who wrote them, are as follows:

"While considering the advantages of a five or six-year technical course we might, on the other hand, give heed to the possibilities of a three and one-half year course in general engineering leading to the degree of B.S., with an additional year, or year and a half (including a full summer), for students who wish to specialize in college."

"See S. P. E. E. papers by W. T. Magruder. My sons are taking these courses."

"I believe that five and six-year engineering courses are desirable but should be optional; in other words, that the student should be allowed to get B.S. for four years of work. Furthermore, in the longer course, I would have much of the additional time devoted largely to general studies rather than special engineering studies, as I believe the weakness of the average technical school graduate consists in his lack of cultural training rather than of technical training."

"I am wholly in sympathy with either five or six-year courses. This amounts to an advanced requirement of admission to engineering schools. The fundamentals of engineering science as they should be taught have become so considerable that the student cannot master them in four years and at the same time acquire a knowledge of those subjects of polite learning that he ought to be somewhat familiar with. I would not increase the amount of technical training, but would put the increase in time wholly into what you have called cultural subjects, including foreign language and English."

"Would it not be better to cover part of this by a higher standard of preparation and the balance through postgraduate work?"

"I am not in sympathy with five or six-year courses."

"Am not in favor of making five or six-year engineering courses for the general student, as I think a great many will waste their time by spending so many years. I would much prefer graduating men with the degree of Bachelor

of Science at the end of four years, and then laying out graduate courses for men who are really competent to continue in the work."

"Do not think it healthy to spend so long a period of time at one school."

"I believe that those who can afford it should take two years in an engineering course, after taking an A.B. degree."

"Thoroughly approve five and six-year courses, if they are on the coöperative or part-time plan."

"I think four years in college and two years practical experience, is best. Am not sure whether it is better to have them alternated or separated."

"It is my belief that students should enter college better prepared especially in English and mental arithmetic. In order to cover properly the subjects that I have mentioned and devote a sufficient amount of time to 'shop-work' a five-year course would probably be necessary and sufficient."

"I see nothing to be gained in the lengthened course."

"It is the only scheme that will give the young man adequate preparation for his profession."

"I think five-year courses desirable; but would not advocate six years for any except the more gifted students."

"Would prefer an extra year of outside practical work to an additional year in the college course. If high school could be robbed to two years then a six-year course—three of 'college' and three of 'university' work would be very good."

"I approve of the five-year and six-year engineering course as tending to turn out better educated men, and therefore men better fitted to meet the competition of the present day."

"There are objections, in my opinion, to the five and six-year courses, chiefly because they oblige a man to start out on his career handicapped by just that much greater age. He will be worth, in my opinion, but little more at the end of a six-year course than at the end of a four-year course, as the experience he needs is that he must get in actual contact with business conditions. It would seem almost more advisable for a student to work during the summer months at shop and field work, and so maintain the four-year course. In other words, when a student graduates and enters the practice of his profession or a business career, he should continue to study and develop, and so make each year really a part of his college course."

"Whether or not a man spends three, four, five or six years in college depends so much upon his ability to pay the bills, his natural ability, the kind of work he thinks he may be able to do and many other considerations that a general rule cannot be laid down. I think it could be safely said that many a man wastes four years in college and he would equally waste five or six years. Four years seems to have been sufficient for the preparation of many able and successful engineers."

"Four years properly utilized is ample. Five or six years more or less improperly utilized is worse than four years properly utilized."

"Do not think it advisable to spend more than four years."

"The ordinary college course should be extended to five years. There is a question whether the six-year course is warranted, at least until the college faculty is improved in proportion to the extension of the college term."

"Five-year and six-year courses are very good for those who can devote that time to college undergraduate work. I would not have all colleges require a longer period than four years for undergraduate work."

"The five or six-year course in engineering would no doubt develop the student along theoretical lines, but at the same time make it harder for him to get acquainted with practical work, and with the practical man's way of doing it."

"I very much question the advisability of establishing five or six-year courses unless it has been pretty well determined that the student is by nature specially gifted for the profession."

"The five and six-year courses fill a definitely felt need. . . . . but the four-year courses should still be open to a fairly large number of students."

"The fifth and sixth years can be used to much better advantage in practise than in the University. The environment of the university is entirely unsuitable for the commercial and practical engineering experience which must be acquired by the technical graduate."

"I don't believe in any courses over four years in length. As a matter of fact, I believe that summer schools and a three-year course should cover what four years did in my time."

"It would seem to me much better to go over each course thoroughly and reduce the amount of work done by the student as much as possible while still retaining the essentials. The time saved could then be devoted more profitably to other subjects."

"Some men would not get enough in ten years, others get plenty in four. The man who hopes to succeed will not stop studying when he gets his diploma. If this could be thoroughly understood by every graduate, they might cut the course to three years."

"I think five years or six years in college too much time taken from the best years of a man's life. The only way I would consider a five-year course would be two years in college, one year at practical work in the line the student proposes to follow, then two years more in college. I would rather prefer to see the time shortened to three years with a faster rate of progress, or in other words, more efficiency."

"A four-year course should be enough to teach a man how to think and where to find information when he wants it."

"Four years is enough for any man, and what he doesn't learn during that time he can readily learn later when he needs the knowledge. This does not apply to graduate work for students specially qualified."

"I am in favor of the six-year course, or as an alternative to raise the entrance requirements. The tendency in the four-year course is to make the graduate narrow, and not well informed. In order to give the necessary technical training in four years the cultural studies must be so slighted that the result is to produce high grade mechanics, rather than broadly trained men capable of filling responsible executive positions to the best advantage."

"These plans are good but we do not need five and six-year engineers, as badly as we need skilled artisans. Therefore, we need trade schools or continuation schools more than five or six-year engineering courses."

"Opposed. If it were merely in pursuit of knowledge, we might very profitably spend our entire life in school."

"Do not believe in the five or six-year courses. Far wiser for the average engineering student, after getting the rudiments of engineering by attending college four years, to spend another one or two years in one of the apprenticeship courses offered by large manufacturing companies. After spending as much as six years at school, a man is likely to find it hard to go to work under a strict master who will not advance him when he makes a barely passing mark, but only when he makes a very good or excellent mark."

"Don't believe the really earnest student can stand five or six-year courses financially. Usually the most earnest are the poorer fellows."

"Four years is ample; might even be cut down to three years to advantage."

"According to present arrangements there are from two to three months of every college year which are not used, and during this time the entire educational equipment is standing idle. This is not efficient, and such long periods of rest do not appear to be necessary."

"It's too long for most parents and it makes most men wait too long for marriage."

"It would be much better for a man to come back for one year after having been out a short time, than to stay at college two or three extra years after his first four. The men in my acquaintance who took the longest courses are the least efficient."

"Students should not be admitted to strictly engineering courses before they are 20 years old. Therefore one or two years previous can well be spent in cultural studies."

"The value of such courses would be greatly enhanced by using each vacation period for practical application of what was learned along specific engineering lines during the preceding semester."

"I believe that two years preliminary 'Arts' training is valuable not only in itself, but further for the ability it gives to pick out the essentials of the technical courses to follow. It has been my observation that the 'Arts' men get more out of their engineering studies than men without the 'Arts' training."

"The five and six-year courses give the student too late a start in his business career."

"It is a great question with most students whether the value in years to come will be worth the delay in getting started."

"Great! Don't compromise on anything less than six years. When I get a chance I am going back to make mine a six-year course."

"In view of the great mass of information and training in thought which an engineer requires, I think there are many arguments for the longer courses. . . . . The average structural steel detailer bears the same relation to the designer that the nurse does to the doctor, yet while the detailer calls himself an engineer the nurse never presumes to refer to himself as doctor. It might be that a divided course in engineering might be given which at the end of four years would fit a man to do the routine work and give a degree which in no manner could be perverted into Engineer. If a person was fitted to continue his studies, he would then get his degree of Engineer. I understand that in the Argentine Republic it

takes about seven years before one can call himself Engineer, and the term is used as a salutation as we use Doctor."

"It has been found necessary for M.D.'s to have 6 years in order to practise and I believe engineers will have to come to the same thing. The present 'culls' could not stick it out for six years, and therefore would be eliminated to a greater extent."

"For the average engineer, the material presented in the four-year course is amply broad as a theoretical start. This, supplemented by a year or two of graduate study along the line of some specialty after a period of six or eight years of practise is far superior to a five or six-year course entirely in preparatory work before entering the practise of the profession. This is obviously due to the perspective gained, in the selection of the essentials of the work, as it is seen in actual application. One need only recall the cases of seniors who remain in college for a year or two as instructors, at the same time taking advanced work—at the end of which time they are frequently found too far advanced in ideas and 'dignity' to accept the minor situations open to the average college graduate."

SUMMARY: On this important question the opinions are so nearly evenly divided that "the Chair is in doubt," and it has, therefore, been considered necessary to present the "pros and cons" very completely by quotations. There is apparently a bare majority against the plan of making five-year and six-year engineering courses compulsory, although nearly everyone is ready to admit the desirability of having the colleges prepared to give training beyond the bare essentials which seem now to be squeezed within the four-year course leading to first degree. There is even a considerable minority composed of those who think that by increasing the efficiency of teachers, courses, and administration, and by utilizing the vacation periods, the engineering training might be cut down to three and one-half or even three years without sacrificing any quality which it has at present.

There seems to be no dissenting from the view that if a student is to attend college longer than four years, he should have some preliminary or intermediate contact with the actualities of business or professional practise. This not only guides him in selecting his more advanced studies, but also increases his enthusiasm and determination, his efficiency in studying, and his appreciation of the values of the knowledge which he is acquiring. If he has already knocked against the world before he finishes his college course, his mature age at graduation is no handicap but rather an advantage. There would appear to be a certain amount of advantage in having some years of practical experience come between the preliminary and the advanced years of the engineering course—that is, in making the latter years practically a graduate course of engineering. Some of this advantage would be in the insurance

that only those men would afford the advanced course whose natural abilities and achievements promised good returns from the additional investment of years.

It is made fairly plain that, if the engineering course must be extended to five or six years, the additional time should be used to broaden the course rather than to specialize it more highly. That is, the present applicational courses may be made more thorough, but the main purpose of the extension should be to furnish opportunity for the student to polish up the human side of himself, upon which his success must depend ultimately more than upon his knowledge of sciences. The cultivation of this side of the student may not be forced by requiring him to take courses for which he has no interest and no ability (as perhaps, for instance, foreign languages) but rather by enabling him to make his own selection of nonprofessional and nonfundamental courses of study under the guidance and inspiration of broadminded faculty members. It should be noted, also, that studies which furnish this particular and desirable kind of culture are not necessarily nor always nonscientific, but may be geology, psychology, sociology, anthropology—in fact, any study which leads to a fuller recognition of the relations of ourselves to our fellow-men and to our Creator.

C. Detail Criticism of Methods of Teaching, Content and Arrangement of Courses.

Question 4a. What things do you think were not taught well enough in college?

Typical answers, arranged in approximate order of seniority of the writers, are as follows:

"If I were to try to do so, I might enumerate a thousand things which I did not get in college, and perhaps a thousand others which I may seem never to have made use of, but these would be idle comments. As I now look at it the training at college in accuracy, perseverance, capacity to think and grow are the fundamentals. Facts upon which others have based conclusions are never facts to you until experience has proved them so. In cultivating the brain do not forget the body, and remember that all the five senses are needed to fully develop the proverbial sixth. It is the sixth sense that counts. Is that miscalled 'horse sense'?"

"English is not properly taught in most engineering schools."

"Physics."

"This depends very largely upon the personality of the teacher, as a poor teacher will get little or nothing out of a good subject, while vice versa, a good

teacher may make not only an interesting course but one of great general value in training a man, even though it may not have very specific bearing upon his engineering course."

"Public speaking, practical application of elementary calculus, free-hand sketching and political economy."

"Students often need to be developed along lines of observation and co-ordination. Composition and essays do not receive enough attention. Spanish has a commercial value to those who expect to enter sales bureaus or Latin countries to the south for executive duties."

"In general, too little stress is laid on *memorizing.*"

"English, the humanities—all that distinguishes between an educated and an ignorant man."

"Shopwork has usually been taught until lately as manual training, which is the wrong point of view."

"The preparatory schools should give the student a thorough foundation in mental arithmetic enabling the student to take ordinary problems orally without repetition and to solve the same orally, step by step, to its solution. Such a training is invaluable discipline for the mind and is necessary preparation for all theoretical engineering work to be undertaken at college. With such a training the time and labor required for the mathematics for any college course will be cut in half or less, leaving a large amount of time available for other important work. The writer was given such a training, when a lad, by his father and has found it of the greatest value. To this preparation alone he attributes his ability to cover his mathematical course with very little instruction and in a very brief time. The mathematics were a great bugbear to many in his class, and the reason lies largely in the lack of adequate fundamental training."

"I would say emphatically that mathematics is the one thing in which the college man is sadly deficient. This is the language of his profession and without an adequate knowledge of it, many fields he might enter will be closed to him."

"Mathematics, mechanics, physics, chemistry."

"The 'tricks of the trade' are not taught well enough in college, and as there isn't time to teach both tricks and fundamentals I would eliminate the tricks. By tricks I mean details of construction and operation which can be learned much better out in practice than in the schoolroom. As I look back on my college work I'm very sure that there was some of it that I failed to appreciate at the time because I didn't know 'what it was all about.'"

"To appear and speak in public; physical training; field work; application of theory. Too much time spent figuring out small things, which in commercial life would be picked out of a reference book."

"When I had been out of college three or four years, I could have told you very definitely just what was wrong with the courses; but now that I have been out eighteen years I am not so sure that there was anything wrong with them."

"Practical mechanics were not well taught. Institutions need practical men, of experience outside of college work, to teach practical mechanics."

"Think the following subjects are not well enough taught in technical schools and colleges: Diction, spelling, the ability to express one's self properly, and the development of decent handwriting. I have been struck with the inability of many engineers of otherwise considerable promise, to express themselves properly and to write a legible, well-spelt, well-written letter. I know of nothing taught at my college which could have been eliminated."

"Things not taught well enough: Mechanical drawing, from the standpoint of economy of time and materials; inadequate introduction to the use of engineering handbooks and compiled data; civil engineering and field work, particularly railroad surveying."

"The greatest criticism that I have to make on college students is their lack of thoroughness; their lack of honesty in the smaller things; their lack of knowledge as to the reasons why they do certain things, and their lack of application."

"This item is not one of those in your list. However, I insert it and term it 'cribbing.' It is possible that matters in this respect are radically different than was the case during my college career. If so there is some other influence now existing which tends to the same results as did 'cribbing' a great many years ago. The American youth as a whole—and I fear that this pertains in a very large measure to college students—is too prone to take chances. This manifests itself particularly in the imparting of knowledge and answering of questions, which, upon investigation, prove inaccurate. There is probably no malicious intent, but lack of thoroughness seems to be a part of their training, making many of the college men particularly weak in the question of reliability and honesty."

"I believe in the utmost thoroughness in fundamentals and, of course, an engineer's fundamentals are mathematics, *physics, mechanics.* The graduate should be so taught, reviewed, drilled, trained, retaught, and tested that he actually

knows, lives and feels the principles, computations and manipulations having to do with composition and resolution of forces, bending moments, resisting moments, torsional stresses, graphical statics, hydraulics, pneumatics, electricity, etc., etc., etc. . . . . No subject was taught well enough—in many cases through lack of time. Many subjects could have been taught better without more time."

"Independent thinking."

"Application and persistent effort."

"The subjects that were at the time I took them not taught well enough were the courses in drawing, the courses in design, and in some respects the courses in mechanics."

"The following subjects are not taught well enough in college: English and economics as applied to present day industrial conditions."

"The only course to which insufficient time was given was that of English and composition."

"The majority of men taking an engineering education, sooner or later become identified primarily with the business side of the various lines of work, and I believe that the average college errs in not preparing the student to a great extent along the lines of economics and business management."

"I cannot recall a single course that was taught well enough."

"Among the things in which I have found that a more thorough grounding would have been desirable are: strength of materials, theory of structures, physics, surveying, engineering contracts and specifications, and commercial law."

"In my own case, I failed to learn to speak and write easily, clearly and to the point."

"I consider that it would be well to increase the proportion of time spent on chemistry, physics, English, business accounting and economics."

"My course in mechanical engineering should have contained rudiments of surveying and use of surveyors' instruments."

"After I began active engineering work, I found that my professional equipment was scanty and I was forced to admit to myself that I was hardly worth the money that I was receiving. I had confidence in myself, however, and a knowledge of how to go about studying a new subject. I might have been saved from occasional embarrassment if my instructors had brought certain things to my attention while I was in school; but, frankly, I have never felt that my success or non-success depended upon what my instructors taught me so much as upon my own courage, energy and determination."

"We occasionally have an alumnus write back, suggesting that this or that thing be taught—something that he has had to learn, perhaps in a mortifying manner. Recently a graduate mentioned horseback riding and packing as something that we should teach. Personally I think that the recent graduate must expect to find himself short in many respects so far as information goes. The time at school is short."

"Foreign languages, especially German and French, were not taught well enough in the college I attended. German could be very well dispensed with and the time given to Spanish and French."

"Not taught well enough in my (electrical engineering) course: English, modern languages, business practice and administration, commercial law, hydraulics and hydraulic practice, thermodynamics, fundamentals in electrical engineering."

"Impressing the proper connection between 'theory' and 'practice,' rather than allowing the popular notion that they are separate and distinct, to take root."

"Languages are not taught well enough in college nor generally in the public schools of the United States. English and economics are not taught well enough in college."

"Modern languages."

"The weakness of the usual engineering education can be attributed largely to a desire to cover much ground without thorough knowledge of the principles involved. Engineering graduates are generally weak in English, business, and cultural subjects. Men having a degree ought *at least* to be able to write an intelligent letter."

"There were several things I thought useless at the time I studied them, which later occurred to me as not receiving enough attention, and vice versa."

"Accuracy and precision should be instilled. While it is impossible to learn *business* in a college course, I think that far too many young engineers (and some old ones) do not appreciate the value of a dollar, consuming time and money on unimportant and irrelevant details. One of the foremost consulting engineers in the country once said that 90 per cent of his engineers were not competent to carry on independently and successfully work of importance, because of their inability to realize this."

"In most engineering schools the relation of engineering to business is too much overlooked. Factory management, organization, and accounting should be given somewhat to a student before he leaves college. I have met graduates who did not seem to know the first thing about a bill of material. They figure strength at school, but never dream of what steel is worth, extras and varying prices, that must be considered later."

"The thing that was taught *me* in the poorest fashion was mathematics. There was absolutely no inspiration nor interest in the subject as presented to me."

"Business English and forms, descriptive geometry and drafting."

"Methods of analyzing a problem into its coördinated parts. By 'problem' I mean study or investigation."

"While at college I probably criticized the faculty like a good many other students, but after having gained a more comprehensive view through outside experience I feel that at least at my Alma Mater (Stevens Institute) a well-balanced course was maintained."

"What are sometimes called 'practicum' courses, such as shop, surveying and drafting room, I think were more poorly taught than others. The instructors had the wrong point of view, for the most part."

"The question is often raised, 'what qualifications in addition to a thorough grasp of fundamental principles and a good judgment in applying them is essential for a young man to succeed in engineering work.' I would say, *power of observation.* A young man who has developed the sense of observation is in a position to supplement his own experience with the experience of others. It will enable him to grasp more quickly the significance of any plan of action and the details of the various steps necessary for its execution. Such a sense will broaden his horizon and temper his judgment. It will enable him to recognize the unforseen circumstances which often arise and defeat the best laid plans. Such qualifications will quickly bring a young man to the attention of his superiors. A study of the men who are recognized as leaders will reveal at once that their power of observation has been developed to a marked degree. Anything which can be done in an engineering course which leads in this direction will be an important aid to a student in his work after graduation."

"I have *now* no fault to find with anything as administered in my course at Purdue. At the time of my graduation I would have answered this differently."

"Insufficient training in the use of English language. Also, many engineering courses do not give a clear conception of the ultimate purpose of engineering which is to accomplish the most with the least money. . . . . To accomplish this the student should be given some sound instruction in administration, of which a clear idea of the principles of accounting is a necessary part. . . . . Why is it that when an engineer proposes some business scheme, he generally, if he succeeds at all, practically turns the cream of it over to the financier and only himself gets a mere clerk's position out of it? It's because the average engineer seldom has a balanced idea of the proper relative costs, or the probable markets, and does not know how to study out these subjects."

"Business law, contracts, specifications."

"Modern languages are not taught well enough in the average technical course. If they are of sufficient importance to remain in the roster, they should be taught in such a manner as to give the student a ready working knowledge of French or German or both; otherwise they might well give place to something else."

"Your questions have been discussed by several college men here at the works, and the answers which follow seem to be the opinion of three or four of them, interested more in mechanical engineering than in any other line. English, machine design, metallurgy, and shop practice, it appears to us now, were not taught well enough in college. English and metallurgy were taught in such a way that they were bone-dry to most students. Machine design could have been taught in a more interesting way and should at least touch upon the cost of different designs. Shop practice was too superficial and too much like a kindergarten. Foreign languages might have been replaced by economics, psychology, accounting and general business principles."

"English should be given more time. Few technical college graduates can write a good letter and are fitted to fill a place in cultured society."

"English composition, business practice, original thought and analysis."

"My instructors in mathematics were *thorough,* but the higher mathematics were taught too much as abstract theories; in other words we were not made to consider the calculus, for example, as a tool with which to get results, but rather as an abstract collection of theorems which must be mastered in order to get the necessary credits to pass."

"Many courses cover too much detail and too few principles. As to subjects, perhaps too much mathematics, especially in some of the higher branches. The whole problem seems to be a question of too little time the student is willing to

give, too much willingness to 'squeeze by,' too many fads (i. e., special subjects), too little knowledge of what he really wants to do, and too much thought of what he thinks he wants."

"It would be well for the average student if more incentive to engage in athletics were offered by the faculty."

"Too many things were memorized, and not enough attention paid to reasoning. No attention was paid to English, spoken or written."

"Corporation finance and organization; economics as applied to construction, operation, management and financing of individual plants; psychology, machine design."

"English, economics, and business organization."

"Public speaking, argumentation, business methods."

SUMMARY: Opinions on this topic depend, naturally, upon the age and experience of the individuals expressing them. Broadened by contact with large affairs, mellowed by age, mindful of the meaning and values rather than of the sensations of life, the older alumnus is fairly content with conditions as they were and are; while the younger engineer who is absorbed in details, buffeted by ever-changing experiences and desperately pressed for time, finds fault with almost every feature of his preliminary education. The former is inclined to regard as of utmost importance the *habits* and the *character-training* which the student acquires at college, while the latter measures the value of his education in terms of facts, laws, skill, information and "courses." Here again is apparent the conflict between what we may designate as the idealistic and the materialistic evaluations of college training.

Let us for a moment incline our ear to the materialists. Gravely they assert that the following subjects which the embryo-engineer should study are either taught poorly or are not taught at all: English—spelling, diction, composition and essays, public speaking; mechanics, applications of theoretical mathematics, mental arithmetic, descriptive geometry; physics; freehand sketching, mechanical drawing, design of structures and of machines; chemistry; engineering contracts and specifications, economics, business management and organization, commercial law, and accounting; strength of materials, theory of structures, surveying, and hydraulics; Spanish and French; metallurgy; psychology; fundamentals of electrical engineering; physical training; handwriting. Not only this, but our courses in shop practice are taught from the wrong viewpoint, and we do not give adequate training in memorizing, in applications of theory, and in the use of engineering handbooks and compiled data. We are moved to wonder whether

any of these critics would be willing to stay in college long enough to qualify in all of these subjects as well as in those to which no objection has been raised.

The demands of the idealists are so much more modest that it is quite feasible for us to attempt a response to them. As to the *content* of the college course, they ask only that it deal with real *fundamentals* of science and of general culture; but, regarding the *ultimate purpose* of education rather than the immediate utility of it, they recommend that we try to train the youth in certain vital *traits of character, mind and morals.* Teachers are advised to design their courses of instruction primarily with a view to inspire the student's enthusiasm, fire his imagination, and discipline his will.

The older men of broader vision testify that the real satisfactions of life come certainly to those who have acquired habits of application, persistence, accuracy, thoroughness, honesty and reliability, observation and coördination, independence in thinking. It is possible for the teacher to create or to develop these qualities in the student, where it is impossible to satisfy the numerous demands of the materialists, because *every* course in the college may be made to contribute its share toward the establishment of these habits, while *specific information* can be treated or emphasized only in *individual courses.* Moreover, these desirable habits are relatively few, and they are inter-related—that is, training in one of them would assist in developing several.

Teachers will probably concede that youthful students respond better to example than to precept. These qualities of mind and character must be exhibited forcefully *by the teachers* in their ordinary and regular work, which is teaching, if the students are expected to acquire them. If our prime object is to establish good habits and character in these plastic undergraduates who are entrusted to our care during the most impressionable period of their lives, rather than to give them a little information which possibly they may use, then the most important qualifications of a teacher are those traits which it is his task to impart—to wit, high personality and enthusiasm rather than great knowledge and skill, if it be impracticable to have all of these in combination. Thus the stu-

dent may be led to acquire capacity to see, to think, and to grow, which opens to him opportunities far beyond those of mere knowledge.

In certain particulars, however, we note a remarkable unanimity of opinion among the materialists. A vast majority of them believe that we should compel the student of engineering to acquire a better knowledge of the use of the English language in both spoken and written discourse, than he seems now to be given. There is an insistent and reasonable complaint that his technical training ignores or places too little stress upon the business of life, upon political and broad social interests and problems, with the result that the engineer does not take that commanding place in the management of human affairs to which his training, his knowledge and his high character entitle him, and that he does not receive his due share of the material benefits of his labors.

There seems also to come from a large number of alumni a specific complaint against the viewpoint and manner in which certain instruction is given. We are advised that the tendency in drawing-room, shop, and laboratory instruction has usually been too much toward the object of developing skill, knowledge, and technique, while the aim should be rather to develop ideas and habits of thought, methods of procedure and of correlation and organization. There is also an insistent demand that we reunite theory with practice—for instance, that we cease shaking the dry skeleton of mathematics which we have stripped of all flesh to satisfy the curiosity of our own matured minds in its anatomy, and that we clothe it and give it a semblance of life so that red-blooded youth may be induced to associate with it by interest and by choice rather than by compulsion. These requests are reasonable, and it is the responsibility of teachers to attempt a response to them.

Question 4b. What things were taught in college that might well have given place to something else?

Typical answers, arranged in the usual order, were as follows:

"I would rather drop some of the more specialized engineering studies and give more attention to fundamentals."

"English and modern languages. Not practical enough."

"Foreign languages, solid trigonometry, modern geometry, Courtenay's calculus, botany, English literature and Christian evidence. There should be substituted more practical application of elementary calculus, a fairly thorough course in choice and

chance and the method of least squares, more freehand sketching of machines and structures, more English debates, public addresses and written reports, text-book recitations on hygiene and physiology, political economy, more geology and lithology, sociology and prime movers." (From a civil engineer, graduated in 1887.)

"Military tactics, French."

"English. History. Too much drawing only and not enough on design."

"English—that is, the reading of a particular series of classic works; astronomy; much of the descriptive geometry; nearly all my laboratory work excepting physics; most of athletics."

"My experience with graduates of technical schools is something like this. Two men will take the same course and stand equally high as regards grades. One will be a success and the other will not, and it is due to one of them having something in his makeup that he could never learn in college. I have seen men who were exceptionally bright in college, who just naturally couldn't connect their education with the practical things of life; and as far as I can see there isn't anything to do about it along the lines of correcting the college course. Leave out all modern languages."

"Foreign languages could be entirely eliminated, and, if necessary, substitute more English and public speaking in their place."

"Ancient history should give way to modern languages."

"I might have left out paleontology, petrography and even some chemistry and devoted the time profitably to structural design, mechanical engineering, electricity, etc." (This from a 1900 mining graduate now in structural engineering work.)

"From my own college experience, I cannot say that too much of this or too little of that was taught. I know that I have found use for all of it, and as but little time was wasted at college, it is unfair to say that something else should have been taught, or something treated more fully. Our opinion as to the training we should receive, will undoubtedly be influenced by the particular branch of engineering we follow."

"In an engineering College I believe that only subjects pertaining to engineering should be taught; not English literature, for although these are essential the candidate for engineering should be well educated in these lines before entering college."

"Purely descriptive courses in all subjects might well have been replaced by principles of organization and finance and possibly commercial law."

"In viewing my college training through a distance of ten years, I do not now see that anything that was then taught me was useless."

"I do not think that the languages are beneficial to any large number of men. I also believe that instruction in public speaking or similar work which would give a man self-confidence could be substituted for English to advantage, and if properly done can cover the same ground."

"German, English, and Elocution." (From a Mine Superintendent, graduated in 1903.)

"It is a waste of time to prepare a thesis in the senior year. An engineering student, except in particular branches such as chemistry, is not qualified after spending three and one-half years in college to do any research work such as *should* be required on a thesis."

"Advanced mathematics, thermodynamics, electrophysics."

"Too much *descriptive* matter in practical courses."

"Freehand drawing, detail design, etc., that can be acquired outside of school."

"Fancy physical measurements, etc., might have given place to economics, finance, management, etc."

"Too much theory on mechanics and thermodynamics, and not enough practice. Eliminate shop work and languages."

"Logic and foreign languages. Logic seems unnecessary in a course which is so replete with work involving mathematics. I am inclined to think that foreign languages should be commenced early in the high school period, and not carried through into the technical school. It is a fallacy to argue that even a rudimental knowledge of such languages enables an engineer to consult reference works outside of his own tongue."

"Foreign languages might well give place to some other subjects. Languages should be made an entrance requirement and part of the time spent on them given to some other cultural subject, such as music, art, architecture, etc. (From a 1906 electrical engineering graduate, now a clergyman.)

"Furthermore, in the sophomore year, if less lectures and more recitations, were had in Physics, there would be fever 'Lit Freshmen' occupying the auditorium while the Sophomore Engineers went canoeing, and much better preparation in Moments of Inertia and Centers of Gravity for the later college years."

"Therefore I would suggest making this study (modern foreign languages) optional in technical courses, and not forcing the engineering student who detests

languages to waste time on them. The elective course in the language could then be arranged to push the interested student along more rapidly."

"That portion of shop work and drawing which develops merely mechanical proficiency. Substitute for it study of drafting-room and shop administration supplemented by *repeated* visits to the shops and drafting-rooms of industrial concerns." (From telephone engineer, graduate 1909.)

"History, English, and Foreign Languages could well be left out. While these subjects are considered necessary to help develop the mind, why not develop the mind with some subjects which would be of more value to the student? . . . . . I would suggest installing Engineering English and have the course practical,—covering say, engineering letters of all kinds, and above all to be taught by an engineer. . . . . I have been told that some day my eight years of German study will be of value to me, but have failed so far to have any use whatever for it. As an example: Since the recent tariff on sugar machinery has been removed and machines are now on the free list, our company has had occasion to purchase some from Germany, and 95 per cent of the words in the ensuing correspondence necessary were not to be found in any of the dictionaries or textbooks the writer had occasion to use in connection with his various courses in German. I therefore consider my eight years time in studying German valueless, and would willingly exchange same for an equal amount of time in steam, gas, or mechanical engineering at large."

SUMMARY: The opinions on this question are summarized in connection with the views expressed on the following question.

Question 4c. What studies should be given in college, that are not likely to be given?

Typical answers are as follows:

"The needs vary each decade. What was needed twenty-five to forty years ago was less theory and more data. Then efficiency was a good slogan—so was directness. Today, *imagination* needs encouragement. The routine of large organizations and high specializations demand that men be first given a wide outlook. They can get the specialization later."

"Some things not included in my college course are of very great importance. I believe that the student should be taught: (a) The purpose, nature and preparation of specifications and their relation to the plans for work; the importance of having the specifications clear, concise, complete and free from ambiguities. (b) The purpose and nature of contracts. (c) The necessity of keeping complete cost data in connection with every piece of work with which he as engineer may be connected. The proper analysis of cost data. (d) The utmost importance of the proper systematic filing of plans, specifications, catalogues and of data relating to the work of his profession. (e) Ethics of the engineering profession. (f) Patents; validity, advantages, and value. (g) Examinations and reports relating to the strength and adequacy of existing structures. (h) The valuation of engineering properties. (i) Business, law, accounting and related subjects."

"A system of indexing articles from technical papers should be emphasized."

"A course in Ethics should be given in place of languages."

"Public speaking."

"Business law, economics, business administration."

"He should at the same time be taught how to bring his abilities to public notice by taking a very active interest in all public affairs. It gives people confidence in a man to see one who has thorough confidence in himself."

"Engineers should study public questions, and take part in discussions of them, and should not leave to lawyers and politicians the moulding of public opinion on subjects in which engineers are capably informed. For an engineer to be able to express himself fluently is a big asset."

"Any course in college training which will develop the social nature of the student, teach him to judge men's motives, to stand for what is right regardless of the current in which he moves, and to take active part in all movements for the betterment of social conditions, will supply a deep-felt want in the engineering profession."

"If it would be possible to include anything in a college course which would give a man patience and stick-to-it-iveness, it should be cultivated. It very often happens that the more brilliant students lack these qualities and that students with less native ability possess these qualities to a greater degree. This is the only way that I can account for what often happens, that ten years after graduation, many of the men who were thought only mediocre students when in school, are far more successful than the brilliant fellows."

"In selecting men for our organization we have found that one of the principal requirements at the present time is to secure men who will be able to meet and deal with The Public and, as a rule, we find that these men are the ones who have been active in the various college societies and athletic teams, particularly if they have been managers of teams or of university publications."

"Also, my observation has been that students fresh from college generally lack the ability to perform a simple calculation or make a simple drawing and *do it accurately*. Is this not the result of the college training which they receive, where the *method* of solution of problems rather than *care* and *accuracy* is aimed at? In my opinion, accuracy should be insisted upon."

"I am prone to think of an engineer as a profesional man, which implies an educated man and a man of character, worthy of commissions of trust. His college work should give him a mind trained for his business, and also a breadth to place him above his business. My criticism of the technical schools as a class is that they turn out men of narrow perspective. I took my own engineering course after high school direct, but regret not taking a liberal arts course with electives leading to engineering work and later taking the balance of the engineering course."

SUMMARY: Opinions as to subjects or studies which should be dropped from or added to the curriculum of an engineering college, when specific are quite varied and confusing. Thus, on the one hand we are importuned to eliminate the college work in astronomy, athletics, advanced mathematics, botany, electrophysics, elocution, English, freehand drawing, foreign languages, geometry, history, shopwork, solid trigonometry, thermodynamics, thesis, logic, and military tactics, as well as all specialized studies, all purely theoretical courses, and all purely descriptive courses. On the other hand, it is recommended that we introduce or strengthen courses in ethics (of the engineering professions), geology, hygiene, physiology, method of least squares, mechanical engineering subjects, patents and patent law, sociology, systems for indexing and filing plans and data, valuations of engineering properties, analysis of cost data—all of these in addition to the myriad subjects which were commended to our attention and efforts, in answers to *Question 4a.*

It is obvious that the recommendations of each correspondent where they are specific are too likely to be dictated by the exigencies of his own situation in life, and it is equally obvious that neither the teacher nor the student could follow them all even if it were wise to attempt to do so. Our advisors are almost unanimous, however, in urging that foreign languages be dropped from the curriculum of engineering colleges; a few voices are raised in defense, but even these are apologetic in tone, pleading that more time be spent on the languages as a means to prevent the waste of all of it. Only slightly less insistent is the demand that more of practical study of the English language be added to the college

course—including exercise in business correspondence and engineering reports, and that concrete examples and practical applications should accompany every study of theory, whether it be in mathematics, mechanics, thermodynamics or any other subject. The student has a right clearly to be told the significance and value of the things he is set to do; he will work better thus, and moreover he will acquire the desirable habit of having always a definite object before he undertakes to do anything.

It would be well, also, for teachers to heed the lone voice which pointed out that the nature of the demands upon them have varied and will vary from decade to decade. We perceive changes not only in the specifications set for the product of the engineering college, but also in the raw material which comes into the college. The wise teacher will not expect to fix his courses and rest; he will be everlastingly trying to improve them, replacing obsolete material and methods with new and better, coördinating and economizing, thus forever keeping his presentation of the subject modern and appropriate while at the same time he keeps himself interested and wide-awake. Then, too, if he is a wise teacher he will keep in mind that he is training men, who must bear the load ten or fifteen years hence, consequently he will try to anticipate the demands that will be made upon the profession. If he aims only to supply needs which are plainly apparent, he is likely to be always a follower, never a leader.

Question 12a. What value do you attach to a knowledge of, or the study of, foreign languages in the engineering college? Would they better be studied elsewhere? Have you found sufficient use or benefit from your language study to warrant the diversion of time from other purposes? Is 10 per cent of a college course too much time to spend on foreign languages? Which languages are most important for an engineer?

Typical answers, arranged in order of seniority, are as follows:

"The study of one foreign language should be all that is required. The choice of language should be left to the student. As soon as a fair reading knowledge is gained, he should be put to work retranslating into English the translation of some standard English writer into the language selected. The student should then compare his translation with the original, in order to improve his own English."

"I believe that the future will show an added value to Spanish from an engineering point of view. The principal value of the study of a foreign language is the training it gives in the expression of other people's ideas by English. In translating you are obliged to get first the idea of the writer and then express it in your own language."

"Too much time is spent on the grammar of foreign languages, while the student perhaps never gets what he needs most, ability to converse and read. Some more simple method should be devised which would easily teach the young student in elementary, high and preparatory schools to converse and read. I have enjoyed my French, but would say in this day Spanish would be valuable. English first, of course."

The chances are ten to one that the college study of a foreign language is a waste of time as far as utility is concerned. I studied French at college and found very little use for it. I studied Spanish outside of college and found it of great use. . . . . As far as the cultural value is concerned, I don't see it. Study English for sure, and if you want to study some other language do it on your own account."

"Had better be studied outside of college. I *have* found sufficient use for foreign language to warrant the study. Ten per cent is more than usual."

"*Not* better studied elsewhere. *Have* found sufficient use to warrant study. Ten per cent is *not* too much. Should be taught for work of practical translation rather than for conversation and construction."

"If there is any time left after a student is taught English, give him a thorough course in one modern language; not a smattering, but enough to enable him to read easily a technical article. If you cannot get the time necessary to do this, give him nothing. Less is waste of time."

"There is good value in a knowledge of foreign language, both French and German. It does not matter whether taught in the engineering college or elsewhere. The *beginning* should be at least as low as the grammar grade. I have found sufficient pleasure in my limited knowledge of foreign language to warrant the time spent on it. I have spent more time on it than is usually allowed in an engineering course of four years, and I have not yet such knowledge as enables me to read either French or German except with great difficulty. Ten per cent is not enough, and as I feel that not this much can be spared from a four-year engineering course, *I would not teach* foreign languages in a four-year engineering course. In a five-year course or a combined course in arts and engineering, I should think that a student should have the equivalent of at least 20 to 22 semester-hours of German or 16 hours of French."

"I do not attach much value to language study, either foreign or English. Language is an ever-changing thing and the only criterion of correctness in the use of words, is whether they are so used by people whose usage is accepted as correct. I have yet to meet an English-speaking graduate who learned enough technical German in college to be of any use to him."

"I think we are wasting time in studying them in the four-year courses. The time can better be spent studying industrial history and economics."

"If a student is 'built that way' give him all the foreign language he will take,—but if he doesn't make fairly rapid progress in his language studies he very probably can spend his time to better advantage in other directions.

"I would dispense with all modern languages in the engineering courses (except possibly chemistry)."

"English, French, German and Spanish should be taught the entire four years. English is very important."

"My own opinion is that a man who has power of application can usually pick up a working knowledge of any foreign language within a reasonable time. From the standpoint of the literature published in foreign languages, I think it is not worth the effort. There is so much literature in English on every branch of the engineering profession that the average engineer has not sufficient time to follow what is published in our own language."

"Elective. It is a mark of culture, and those who can afford it should by all means know Latin, and possibly French, in preference to any other language."

"Those who go farthest in their professions are those who know how to employ others to do their work for them. The ability to translate an article in a foreign language may or may not be therefore an advantage. It all depends on the man and his life work."

"A small amount of work in reading foreign technical publications should supplement an entrance requirement as to ability in one or more foreign languages."

"I have not found sufficient use from my knowledge of Spanish and German (not learned in college course) to warrant any diversion of time from fundamental subjects. Such a knowledge may be considered to be merely a tool and we can afford to get along for a while without a full set of tools. These languages may be learned by anyone at any time by a correspondence—phonographic method."

"Foreign languages are very desirable but should be studied elsewhere. The most essential of all languages is good English for the engineer."

"Unless a sufficient amount of time (not less than two years) is devoted to the study of a foreign language, the time is wasted because a less amount of

study will not give ability to read at sight. Any language training might be an entrance requirement but should not be a part of the curriculum of an engineering school except for those who *elect it and spend a sufficient amount of time* upon it to *become proficient in its use.*"

"I think foreign languages in engineering courses are excellent. I should not think 10% of the college course too much to spend on them."

"As a rule the study of foreign languages is a waste of time to the engineer. In the case of mining engineers a knowledge of Spanish is desirable from a practical standpoint."

"The study of foreign languages should be entirely elective, and not compulsory. I have not found any use for the language I studied."

"The study of foreign languages in engineering is doubtless open to much discussion. I doubt if many engineers derive much practical benefit from their language study. In my own case the German I learned in college has profited me nothing, while those languages which I have found use for (French and Spanish) I acquired as the need arose and in much less time than would have been required in classes. . . . . I should say the time for foreign languages is in the preparatory school and that to English should be devoted that portion of the college course which now includes a foreign language."

"In my own case I have had no practical use for foreign languages, but I do not begrudge the time I spent on them (French and German) while in college."

"I think that a college man should be master of at least one foreign language. I am a firm believer of 'class.' I like a classy performer in almost any field of endeavor and I admire a classy piece of work. To my way of thinking a perfect command of English is one of the essentials of higher education; a college man who cannot express himself is an incongruity. In my opinion a knowledge of some language other than English is necessary to a perfect knowledge of English itself. There are other reasons. The study of a foreign language has a broadening influence in several directions. Almost any engineering work can be carried on without involving, directly, the use of a foreign language. Perhaps it is not really essential to the engineer, but I think myself that it is—that the engineer should be a man of broad interests and wide influence rather than a simple artisan. . . . . In my opinion, the reason so many students of engineering have trouble with foreign language is because they do not understand English as they should."

"Anything less than a working knowledge is useless for an engineer. Even if a working knowledge could be acquired, there is a grave question whether it would be worth the time and energy expended. In the ten years since I left the university I have only recently had occasion to use my knowledge of German, in corresponding with a German firm with whom we have a contract. My command of German was, however, not obtained at the university."

"My knowledge of French and German was barely sufficient to see me through the entrance examinations. Since that time they have been of practically no use to me, and I have almost forgotten them. I wouldn't recommend diverting even 1% from other things to study languages."

"I have found practically no direct application for the foreign language I studied. I am gad to have it, however, as a matter of general training."

"Devote the time to English and public speaking."

"The one thing not taught well enough in college nor in public schools generally in the U. S. A. is modern languages. I have talked with a great number of engineers who were born and educated on the continent of Europe; they all studied English, French and German during their whole school career. As children they were taught not only the rudiments of grammar of their own language, but also of other languages at the same time. This should be done in our *own* common school system."

"I speak French fluently, have a good knowledge of Spanish, and know *some* German. I keep these up for the pleasure they give me. Their professional value has been negligible."

"I would eliminate all foreign languages from the course, but would require a stiff examination in one of them for entrance."

"While foreign languages are valuable as a means of broadening a man's outlook, still I am not sure but that equal, if not better results, could be obtained by substituting the study of English for foreign languages."

"In so far as the study of foreign languages is of assistance in gaining an understanding of the English language it is highly desirable. . . . . Personally, I have always found it economy to hire someone to do my translating rather than to take time for it."

"However convenient the use of French and Spanish is to us, it is not essential to the welfare of the business (manufacturing and exporting of sawmill and woodworking machinery), for business translations are to be had from almost any of our exporting connections at small, if any, cost."

"None of us (a group of four college-bred engineers) have found sufficient use or benefit from our language study to warrant the time spent on it in college."

"I consider the study of foreign languages quite necessary for proper mental development and to prevent a man from becoming mentally lop-sided. . . . . I have found little direct use for my knowledge of French and German except in that it gave me a better knowledge of English and has furnished many useful words and phrases which cannot be well expressed in our own tongue. I do not consider ten per cent too much time to spend on foreign languages."

"From a business standpoint, foreign languages have been of no value to me, consequently my study of foreign engineering literature was useless; but as I grow older I wish I knew more about the foreign languages as a matter of refinement."

"Personally, the years I have spent in Porto Rico trying to learn Spanish, make me wish that I had been wise enough to have taken Spanish in college."

"If it were possible, every man should have at least two years of an academic course, but not being able to get this, the time he spends on foreign languages in a technical course is well spent. Ten per cent seems a pretty large allowance."

"No languages were taught at Houghton (College of Mines) in my time. Since started, and I think a good idea. Most of the young fellows who entered with me, fresh out of high school, couldn't write a decent application for a job."

"Languages have no place in the engineering course. I have worked in a Spanish country and felt no embarrassment due to the lack of Spanish in my course. English should be thoroughly covered in high schools, where a terrible amount of time is wasted."

"Foreign languages should not be studied in an engineering course. There is neither time nor need to learn to speak a foreign language fluently, and I find that for reading purposes the amount of training in languages received in the preparatory school together with home instruction and a good dictionary are amply sufficient."

SUMMARY: On this question the diversity of opinion and practice among teachers of engineering is probably greater than upon any other; therefore, it should be particularly interesting and important to have here a free expression of views, from alumni. The judgment of a large majority of these is that the study of foreign languages should not be required in colleges of engineering—certainly not in a four-year training wherein even the essentials of engineering science must be treated too briefly. Many of the individuals within this adverse majority believe that elective courses in foreign language should be available to students in the engineering college, but that the time spent on such courses should not relieve the student from any essential or fundamental studies. Even those alumni who appreciate the disciplinary value of certain language courses do not claim that such discipline is as valuable to the undergraduate engineer as the discipline of scientific studies open to him. Many believe that *all* language training should be delegated to the preparatory school, much of it perhaps even to the grammar school or grade school. There seems to be a sound basis for such belief, for ability to assimilate languages depends upon power of memory rather than of reason, and in youth the memory is naturally developed much earlier than the reasoning power.

It is quite generally conceded even by those who advocate language study in the engineering college, that knowledge of foreign language is not ordinarily necessary for progress in the engineering profession or in business—in fact, that such knowledge is so infrequently called for that it is quite likely to be forgotten or to become virtually useless, unless practiced from some other motive than necessity. By such advocates the real significance and value of foreign language study is stated to be primarily not the utility of the language—the ability to read or to converse readily in it, but rather the greater understanding and facility which is reflected in the student's use of his own language (English or 'American') ; the pleasure which he may take in feeling that the foreigner's thoughts are not sealed to him and that the foreigner's words are not gibberish ; and the international understanding and broadly cultural exchange of ideas which may come from a more general battering-down of the barrier of language. One cannot help remarking how many engineers who studied foreign languages but have not been required to use them, nevertheless do not regret the expenditure of time. It would appear that in general engineers are not unappreciative of the cultural and æsthetic activities of life, but rather that their common sense and their practical regard for efficiency compel them to believe that man can no more be *forced* to acquire "culture" than a horse can be forced to drink water.

In the opinions expressed on this topic there are several suggestions of value to teachers of language. Too generally the study of foreign language degenerates into mere mechanical exercise in translation of words, instead of being a training in feeling the meaning of the language as a child learns to feel the meaning of words in his own native tongue. Ordinarily and wrongly, also, teachers of foreign languages place too much time and emphasis upon the grammar and the rhetoric and the *use* of the language, although the students would benefit much more by spending the time in acquiring facility and speed in extracting the *meaning* of the language. For teachers of engineering there is a suggestion that no language study be undertaken unless enough time can be

devoted to it to acquire the knowledge *thoroughly,* and that the student be required to *use* such knowledge continuously throughout his college course so as not to lose it but rather to improve it.

Question 12b. How about the study of English language?

Typical answers, in the usual order, are as follows:

"English first by all means; then one foreign language—it matters little what."

"Study of English is very essential. It is frequently taught inefficiently."

"Lack of English is the greatest drawback among American engineers. They should be impressed, upon entering college, that English is as essential as mathematics and science, and that it is not a subject to be avoided wherever possible."

"Composition and essays do not receive enough attention."

"More stress on English composition."

"The one most essential thing to be taught in a technical school is the English language. Nine-tenths of the applied science taught a boy in college may be of no use to him owing to circumstances, except as mental training. He cannot forsee the future and his life may be ordered very differently from what he is planning when in college. On the other hand, in whatever paths his life may lie, a knowledge of correct English will always be of the greatest advantage to him. I have known more than one graduate of technical schools whose grammar was so bad that it showed as soon as he spoke that he had never been educated."

"English is more important than any foreign language. There should be a sound training in descriptive and expository writing and public speaking."

"Brief, clear, and exact *American* is one of the engineer's tools, and he should be able to use it as such."

"As a requirement to admission he should be thoroughly grounded in the use of the English language; for success in any line of endeavor, a knowledge of facts is of small value unless the man is able properly to arrange the facts, draw the proper conclusions and *express his conclusions clearly and concisely in such manner as to convince his audience.* A rigorous training in the use of English given by the preparatory schools is absolutely essential. . . . . Such training must not be sacrificed for anything. Ability to express oneself clearly in his own language increases his self-confidence, his standing among men. Such training will enable him to acquire readily, after graduation, an immense amount of knowledge that is needed from day to day and, after all, the facts that he will acquire in college are but a very small part of the facts needed in the practice of his profession. Under present conditions I can hardly lay sufficient emphasis on the question of English, which should be given careful attention throughout the entire course."

"I can hardly speak for the engineer, since I am an architect. Every college student must have a fair command of English. There is a woeful deficiency in this respect at present."

"But English—that is different—for English is a tool a technical man cannot dispense with. The more refined the tool, the better will it retain its edge and the more finished will be the product of the workman who uses it correctly."

"English should have been thoroughly mastered before entering college, and training once a week in public speaking should teach them some mastery of a vocabulary."

"English is all-important, and we have a lot of engineering graduates who know very little about it. Whether it should be taught in college or not is a question, but I rather favor the Cornell entrance requirement where *every entrant* has to pass the English examination."

"Substitute English and Public Speaking for foreign language. These subjects are important above everything else."

"One hears much complaint about the English of engineering students. I consider this a reflection upon their preparatory schooling and upon the English they have heard in their homes. More interest should be aroused in the thorough teaching of English in the graded schools and in the homes of the students."

"Raise the entrance requirements in English for all except foreign students."

"English is very important; should be taught all four years."

"It is most pitiable to see an engineer make out a report for a body of men in such a way that it fairly staggers them with technical words, and the point to be brought out is so obscured that the report does not carry the weight it should. Engineers should learn to address the public, and learn to express themselves in everyday terms."

"I think English courses are perhaps the most important given for if you cannot write and cannot talk, even a great amount of knowledge doesn't do you much good. I should be strongly in favor of having English taught to engineers throughout the whole four years' course. The American college student is very much under-educated as to English."

"As engineers seem to be notoriously ignorant of such essentials as grammar, punctuation, rhetoric and self-expression the study of English should certainly not be curtailed. An appreciation of literature should be inculcated."

"It is most desirable (and in the long run will save much time) for the engineer to know the English language well."

"A course of study of the English language is exceedingly important and should by all means be included in the required studies of the engineering course. The proper teaching of English is a very vexatious question. I believe it is generally conceded that the subject is not taught effectively to engineers, but a better method must be devised before the old one can be abandoned. In the first place, the cause should be dominantly commercial rather than literary, and the literary part of it should be more practical, and should be entirely divorced from Homer and the Iliad. In the second place, the instructors in other branches should examine all papers submitted by the student for errors of English and Grammar, as well as in subject matter throughout the course. In this way, I believe, the student could be impressed with the importance of the proper handling of the English language. I do not believe this would entail any great hardship on the instructors, as errors of English and grammar 'jump up and bite you' and do not require critical search."

"I think that a student should have had most of his English work before entering upon his engineering course; in fact, his English course should have started when he was eighteen months old, and have been largely completed when he entered high school."

"I have noticed much poor English written by otherwise good engineers. This is a pity, because it gives the reader a wrong impression."

"English is too much neglected. In general I think sufficient time is spent reading different authors, but the lack is in composition. A majority (that is not too strong either) of the engineers with whom I have had correspondence, either cannot or will not write English that is definite and easily understood; ambiguity is a common sin, and crisp, clean-cut sentences that go to the point are rare. Part of this is due to hazy thinking but much can be laid to lack of ability to compose logically and to the handicap of a limited vocabulary resulting in poor choice of words. I think that all laboratory reports, engineering reports, examination and test papers and the like, should be graded also for English by the Department of English. Also, a brief course in business correspondence should be incorporated in the English course."

"More attention to English, to develop an ability to choose words which will enable a man to say what he means."

"No time in college for English *literature*. I *do* believe that engineering students should be taught to express themselves clearly and in as few words as possible. This should be taught the student in connection with his everyday classroom work and should *not* be limited to an English class of a couple of hours per week."

"More emphasis should be laid on the study of English and those kindred subjects which will enable an engineer properly to set forth his thoughts. I have known men who could talk for half an hour in explaining something which could have been covered in five minutes, and when they were done you knew no more about the subject than when they started."

SUMMARY: These representative quotations indicate plainly the fact, that opinion is unanimously and overwhelmingly in favor of more or better study of English by engineering students than seems now to be in evidence. The great majority of graduates when they leave American engineering colleges are palpably and disgracefully weak and ineffective in their efforts to think what to say and in their ability to say what they think. The engineer's chief business is the making or the discussion of specifications, proposals and contracts, in terms and manner which should be clear and unequivocal, simple and interesting. He must know enough

of the meaning and use of words to be able to talk smoothly and with elegant simplicity while his mind is concentrated on the thought which he wishes to convey rather than upon the mechanism of conveyance.

Certainly as we know that some things *cannot* be taught well in college, so certainly also do we know that English is one of the things that *can* be taught perfectly in college. Acknowledging the transcedent importance of good English and the feasibility of teaching it well in school, faculties of engineering colleges would be indeed negligent of their duty to students and of their responsibility to society if they were to continue graduating men whose use of their native language gives the impression that they are uneducated. If the faculties of engineering colleges hold, with certain alumni quoted herein, that such responsibility rests with the secondary schools, then clearly it is their own duty to assure themselves by rigorous examinations that every student entering college possesses the requisite ability to handle the English language with propriety and ease, and it is their duty also to make sure that the student retains and improves this ability throughout his course in the engineering college.

Many alumni engaged in the practice of engineering, as well as many teachers who (like the writer) have studied carefully the technique of teaching, believe that such expertness and facility as the engineer must have in the use of English cannot be acquired by brief studies or by immature minds, and that, therefore, adequate means should be provided in the engineering college for developing the student along this line, steadily and consistently during all four years of his course. It is not necessary, perhaps not even desirable, to set aside during all this time separate periods for the formal study of English language; rather, we contemplate creating a stimulus toward studious use of the language in all the ordinary and informal activities of the student. While it may be difficult for a student to control habits of careless expression which originated in negligence or ignorance at home, much assistance would be rendered if every member of the teaching staff would be circumspect in his own use of language and would watch carefully the language which his students use, regardless what may be the

ostensible object of the instruction he is engaged to give. Strangely, there are many people who use elegant English on occasion, but not ordinarily; such habits tend to forfeit respect, and should, therefore, be discouraged.

Much of the inefficacy and dullness of English instruction as now administered in most colleges (with a few notable exceptions) may be traced back to the personality of the typical instructor of English, rather than to any inherent lack of attractiveness in the subject itself. If we choose to go farther back, we may place the blame squarely upon the shoulders of those who have the authority to determine what shall be the incentive for men who have proper personalities, to engage in the teaching of English and in the improvement of such instruction. The courses are not likely to be more practical or more virile than the men who teach them; and virile, practical men are not likely to submit themselves to such distinctions of salary, opportunity and caste as are too frequently imposed at present by administrators of engineering colleges and indeed quite generally by the sentiment or thoughtlessness of engineering college faculties and of practising engineers.

By intelligent study of the temperament and necessities of the engineering student, and without increasing the actual amount of work required for instruction, teachers of English may *pull themselves* out of the "mollycoddle" category in which the engineers are likely to place them. Though we grant that the best means to acquire and control a vocabulary are to read and study good literature and to write or speak compositions of our own, nevertheless, it must be plain to us that the youth who would be determined to study engineering is not the youth who could be interested in catching elusive fine points of poems, or in writing a composition about a topic which bears not even the remotest relation to his purposes. This young man who attempts engineering is of the type which is interested in force and action, in practical ideas and plain talk about useful and concrete things. The instructor of English should devise means for using as far as possible material which has technical interest and also technical value for the

student. The exercises in composition which he requires may be reports on experiments in the laboratory or on trips of inspection in the field, papers or discussions prepared for student societies or student publications, advertisements of meetings—material of which there is boundless wealth within the ordinary range of student activities but which the engineering student does not ordinarily perceive the value of cultivating.

Coöperation should be active between instructors of engineering and of English, as all parties concerned would profit thereby. The former must watch incessantly the use of language by himself and by his students, if the instruction in English is to be effective; the latter must have some interests and accomplishments beyond and above the mere mechanism of language, and he must practice his art of expression in a vital manner, if he would win the respect and interest of his students.

Question 13a. How far should mathematics study be carried in college by engineers?

Typical answers, in the usual order (of seniority):

"College mathematics should include elementary differential and integral calculus, with plenty of practical applications. Rather than have the calculus cremated because so few understand its philosophy, it had better be first taught in a brief preliminary course, as a method of approximation. For this, as well as for the practical use of the average student, the infinitesimal method is preferable to the method of limits. After a number of the simpler practical applications of both the differential and integral calculus have been worked out, the student will have a definite idea of the nature and scope of the science, for then, and then only, is the average mind prepared to grasp the true meaning of that which has previously been learned by rule."

"No engineer is worthy of the name unless he can use the calculus when occasion requires. Farther than this it is hardly necessary to go. The man who can not understand and use the calculus is at the mercy of the formulas in the handbook and has no means of verifying them."

"I believe in plenty of elementary mathematics as far as differential and integral calculus inclusive, with enough practical applications to give a man a working knowledge of everything he studies, that he can always use when required."

"All engineering students should be thoroughly grounded in geometry, trigonometry, analytical geometry, differential and integral calculus. Electrical students should go further."

"Mathematics should be studied continually in some form. What is now given in four years should be required in two, other things giving place to it. The calculus especially should be more thoroughly taught. When I was at school, hyperbolic and elliptic functions, functions involving three variables so useful in thermodynamics, and differential equations were not even mentioned."

"An engineering student should have a very thorough knowledge of mathematics. The chances are that he will never know more of this subject than he learns in college, while in matters of practical engineering he will learn far more after graduation than before. Give him such training in geometry, trigonometry, and descriptive geometry that he can use them swiftly and surely. Practical examples in these subjects as well as in calculus should be given in great numbers. There is no reason why mental training and practical knowledge should not go hand in hand, in these subjects.

"Should be carried through calculus and differential equations, and least squares should be taught somewhere."

"Through applied mechanics at least."

" 'Higher Mathematics' is not an absolutely requisite fundamental to technical success—but for the man who is naturally adapted to mathematics it may be a ladder by means of which he can climb high."

"The mining engineer does not require mathematics so much in his work as other engineers. However, I believe that a study of mathematics is most useful as a training for the mind, teaching among other things *accuracy,* and developing the powers of analysis."

"Too much time is spent on higher mathematics. Have never had occasion to use calculus, nor have I ever seen anyone make use of it since leaving school."

"There is not sufficient stress on the *application* of the mathematics taught."

"Although I have made very little use of calculus, I would not like to be without it."

"I have regretted exceedingly the *manner* in which mathematics has been taught."

"For the civil and mining engineer, I would advise a thorough training in mathematics up to and including calculus. I very much regret that I did not obtain a better education in mathematics, which is valuable as a mode of mental discipline and also for practical application in my work."

"Mathematics should be taught through calculus but there is considerable room for improvement in the method of teaching this subject as applied to engineering problems, and it should be taught by engineers rather than by mathematicians."

"I have definite ideas on this point. I have a boy growing up. I want him to take just as much mathematics as he can. In my own case I feel that I have not had sufficient mathematics. In my opinion the criterion should not be, what is the minimum that a student should take, but how much can he manage to take. I believe that we could with profit, replace some of the more technical subjects with mathematics and that great stress should be laid on what is taught."

"In general mathematics should be carried through differential and integral calculus, and for electrical engineers should embrace hyperbolic functions and enter into a thorough consideration of complex imaginaries."

"As far as they can stand it."

SUMMARY: At the end of question thirteen will be found a collective summary for all parts of it.

Question 13b. Have you regretted the time spent on any mathematics for which you have not found practical use in your experience? What branch?

Typical answers are as follows:

"No regrets. Mathematics are best training for logical and accurate thinking. Mathematics should be taught abstractly, but most engineering subjects weave in its applications." (This is from a mining engineer, operator and manager of coal mines, graduated in 1886.)

"I do not regret a moment of the time spent on mathematics."

"Yes, on quarternions and on Forsythe's differential equations." (This is from a mechanical engineer, graduated in 1881.)

"No, I have found practical use for almost all that I have had, and could have used some that I have not."

"Others can answer this much better than I. Personally, the calculus and advanced analytics were distasteful chiefly on account of the subjects being poorly taught, but I have never regretted having taken them."

"For instance, a large part of the time devoted to pure mathematics would better have been devoted to the study of the principles of business. The mathematics was good mental drill, but it was not applied at the time to engineering problems in such a way as to become a tool for the easy handling of engineering analysis—consequently it was soon forgotten and in a few years became as so much Greek."

"I have not regretted the time spent on mathematics, although I have not used my higher mathematics, possibly because I am not practising engineering pure and simple. The mental discipline is most valuable but I think the practical and concrete manner of study is better than the abstract."

"Never regretted any time spent on mathematics, although I rarely use any mathematics."

"The majority of engineering graduates lose, within a few years, their active working knowledge of higher mathematics, because their work does not deal, primarily, with problems involving these mathematics. At the same time, they retain an ability to understand mathematical deductions which is sufficient for ordinary purposes."

"I approve the course in mathematics as given at Columbia University. Much of it, such as calculus, I have never used—or think I haven't, and have forgotten—or think I have. But really I feel that it became a part of me, and I have never regretted the time spent on it." (From an electrical engineer graduated in 1905.)

"The study of mathematics by engineering students, should be thorough. I do not regret the time spent on this subject even though I have found no practical use for the higher branches of mathematics."

Question 13c. Is mathematics more valuable when taught abstractly, by mathematicians, as a mode of mental discipline, or when taught in a very practical and concrete manner, in intimate connection with its uses, as by engineers, so that it becomes not a subject apart but rather an habitual method of thinking in all things?

Typical answers, arranged in the usual order, are as follows:

"I believe mathematics should be taught in the logical way by mathematicians, the applications to be made later in applied mechanics. There should, however, be coördination and mutual understanding in this work."

"Not abstractly. Should be taught in connection with its uses. Do not divorce the practice from the theory."

"Mathematics is too generally taught abstractly, and while the training may be good, many students lose interest in the subject on account of the abstractness. Concrete mathematics is much more valuable than the abstract, and I see no reason why it should not be equally good as mental training."

"In connection with its uses, as by an engineer, yes. Take an ordinarily intelligent man and teach him the essential applications of trigonometry in three days. It should be possible to equip the student with the applications of mathematics so that it would never be necessary to refer to the fundamental steps in later life. Contrast the grasp of arithmetic with that of integration, in the majority of engineers."

"The only way to teach mathematics to engineers is to teach it in the way he will ever afterward meet with it in books written upon engineering subjects."

"The mathematical habit of thought will develop in active life."

"The student should be taught to use mathematics as a tool of thought just as he is taught the use of a planer as a tool for shaping iron, leaving the philosophical aspect for the consideration of the mathematican just as the design of the planer is left for the consideration of the man who is to specialize in machine design. The mathematics teacher need not necessarily be an engineer but he should know physics in order that he may be able to put everyday problems into mathematical form and interpret the mathematical results. These two processes are at present almost totally lacking in our mathematical teaching."

"Thoroughly. Very practical; should be at fingers' ends. My idea of method of educating even in pure mathematics, and especially in theory of structures, is a thorough explanation by instructor and application by student. The fundamentals of statics were taught in this way, and the three conditions of equilibrium and the basic principles remain indelibly impressed."

"Without teaching experience it is perhaps presumption to give the following opinion. It seems, however, to me that there is a lot of hocus-pocus with reference to the value attached to certain studies as mind developers or mental discipline agents. I have seen so many men without education who have acquired brilliant mental efficiency from reading and conversation, along the lines of their chosen work only, that I doubt whether the study of Greek, Latin, English composition and many other such subjects, along with some of the pure mathematics, is not a waste of time and that the student could be given instead more practical studies which will not only develop his mind but furnish him with something he could sell in the market."

"Mathematics as taught by the ordinary professor is of little use except as mental discipline. The professor can seldom make any practical use of his subject

himself—that is, if he has an abstract engineering problem given him the chances are that he could not solve it, or if he did it would probably be wrong due to false premises. In other words he is not a practical man, or he wouldn't be a professor of mathematics. I never could see any use of conic sections as a subject, but I suppose it will always be taught in college. I never met a college graduate in engineering work who could make any use of it if he wanted to. Algebra is the one subject with which a student should be thoroughly soaked. It should be taught thoroughly during the freshman year, and the rest would be easy. Without a proper foundation there is no use in trying to think in mathematical equations."

"There is not sufficient stress laid upon *applications* of the mathematics. This is also true of mechanics."

"Mathematics could profitably be taught by engineers, and where convenient or possible, engineering problems should be used."

"The average college does not waste time on this subject. Students should have the abstract instruction in the mathematics department, and the concrete applications under the departments of physics and engineering.

"I believe that Cornell University has made a wise innovation when graduate mechanical engineers were made professors of Applied Mechanics and of Descriptive Geometry, to have charge of the courses in these subjects for mechanical engineers."

"Such subjects should be taught as far as may be in a practical and concrete manner but where abstractness is necessary it must not be shunned."

"If engineering applications are used for the problems involved in the courses of mathematics, it seems the greatest amount of good would be obtained, and the mental discipline is in no way inferior to that obtained in courses taught abstractly."

"It should be taught with its application to practical technical problems constantly in view. The greatest difficulty with the mathematical training of the average student is that he cannot express a physical problem in mathematical terms."

"The question as to whether mathematics should be taught by professional mathematicians or by engineers is an important one. If taught by mathematicians, it is apt to become a mere abstract subject which the average student does not fully comprehend, and if taught by engineers is apt to be done in a very loose and imperfect manner, as, so far as I have been able to observe, the average engineering professor is not a very good mathematician. It would seem to me that the better way would be to have the student study elementary mechanics given by engineers at the same time he is being taught calculus by the mathematicians."

"Mathematics is more valuable and is studied with greater enthusiasm when taught in intimate connection with its uses, as by engineers, than when taught as a thing apart, to be learned as a matter of mental discipline. The engineer is not apt to like mathematics for itself alone."

"Mathematics as now taught covers sufficient ground, but should be covered more thoroughly, and with greater emphasis on the practical applications. Theory and practice do not conflict here in the least and the mental processes involved in working out a practical problem are just as valuable for mental discipline and for the development of habits of clear thinking, as abstract examples. To my mind mathematics is by far the most important subject taught to engineers from both practical and academic points of view."

"It would seem to me that mathematics taught in an abstract way with simply here and there suggested applications covers the ground as well as possible. Emphasizing the applications unduly would tend to obscure the principles."

"Thoroughness should be insisted upon first, last and always. I would have mathematics taught as an abstract science for the purpose of developing the reasoning powers of the student. I would have it taught also in its practical application."

"Personally I enjoyed mathematics more as an abstract science, but have since regretted that it was not taught to us as a working tool, and as a means to an end rather than an end in itself."

"The truth is, too many men go in for engineering because it 'pays.' The howlers against mathematics are the men who 'get there' for administrative positions. If success is measured by *pay*, it is better not to have engineering colleges."

"To be specific, the really useful part of trigonometry, from the standpoint of the engineer, can be acquired and amply illustrated in a very short time and in a very easy fashion. What, then, is to be gained by spending the greater part of a semester in proving identities and deriving many useless formulæ? Yet this is just what is being done. To some degree, the same criticism holds for the calculus. It is therefore most desirable that the mathematics should be taught by engineers. . . . . I do not think that too much time is spent on the mathematics. The trouble is that the student acquires a certain proficiency in the art of juggling

mathematical symbols rather than facility in the use of mathematics as a medium for the expression of thought."

"I do not think that 'mental discipline' in mathematics is as good as 'mental discipline' in practical subjects."

"As a mental developer, mathematics is not in it with Latin. Teach the boys to think mathematically by showing the application to engineering problems. This thinking habit is not developed by dry and abstract mathematics. It is developed by the solution of problems that can be illustrated in real life-work."

"In my estimation the usual trouble with students is that they do not learn their mathematics well enough to interpret it. This might be partly remedied by having the subject taught by engineers with constant interpretation and application."

"It is too often the case that a student does not appreciate the relation between such subjects and his chosen work, and that upon graduation he finds that he is unable to apply the fund of knowledge which he has gained in his college course."

"If mathematics could be taught in conjunction with its application to engineering problems, it would make a more lasting impression upon the student."

"I think most colleges would do well to raise the entrance requirements in mathematics for engineering matriculates."

"It should be taught by those who are able to see the correct application of engineering principles yet it should not be made so practical that the engineer would not be able, if called upon to do so, to apply the theoretical side of his mathematical training to the solving of some new theory in engineering."

"A man might forget some complicated integration as an integration, but show him where it is useful and it isn't so soon forgotten."

"Mathematics should be the last thing an engineer should stop. It should be carried through differential equations at least. I specialized in mathematics and would have taken more if time had allowed. Even though I have not found use for much that I took, I believe it to be the best of all mind-developing subjects. I would advise that it be taught in intimate connection with its uses."

"Mathematics should be taught by mathematicians, and not slighted. The applications come easily if the grounding is good."

"In the writer's opinion, mathematics, particularly the calculus, might be presented in more workable form, as the greater difficulty, in everyday experience comes not from unfamiliarity with the mathematics itself, but rather in its application to the problem at hand. The University of California offers an elective course in junior year entitled 'Application of the Calculus' which the writer has found immensely helpful. Even when presented in this practical form, there is no reason why the mathematics should, in any great measure, lose its value for mental discipline."

"In order to use mathematics as a tool intelligently and with originality it is necessary to have a fair understanding of pure mathematics as such. It is necessary to have a bird's-eye view of this science in order to best see the extent of its applicability. Now, I am of the opinion that this bird's-eye view cannot be obtained by only having in mind the idea of mathematics as a tool; with only this idea in mind a certain mathematical insight is lost and the mental discipline derived from such a study is very little. Now, there are instructors of mathematics in engineering schools who have studied no more mathematics than that given in an engineering course. I would ask; How can they give their students a bird's-eye view of this science? How can they impart anything like a mathematical habit of mind? How can they make their students appreciate the various possibilities of applying mathematics to engineering? This condition does not exist in the large universities as far as I know, for the instructors of mathematics there are primarily mathematicians. They should be so everywhere."

"Carry mathematics as far as possible—for the entire four years. I have had no mathematics in my college course for which I have had no practical use since graduating, but I have been in special work and realize that few men would need so much (70 hours total)."

"Mathematics should be taught abstractly except that a course in applied mathematics should be given by an engineer."

SUMMARY: The mathematical equipment of every engineer, in the opinion of a large majority of our correspondents, should include arithmetic, geometry, advanced algebra, trigonometry, analytic geometry, differential and integral calculus. A course in least squares would be distinctly advantageous in many lines of work. Electrical engineers need also a knowledge of hyperbolic

functions, algebra of complex imaginary quantities, and differential equations. In the present state of their development, some branches of the engineering profession seem to require less of mathematics than other branches require—for instance, mining engineering and perhaps chemical engineering. But we should be reminded that the college is preparing its students for the unknown future, and not for the present or the past activities of the professions. Twenty years ago mathematics which is now necessary to the successful electrical engineer appeared as irrelevant to the profession as astronomy or botany; the highest developments today are being achieved by men who at that time might have been considered as physicists, mathematicians or chemists rather than as engineers.

While few engineers find fault with the *amount* of mathematics which is taught to students in engineering colleges, many alumni advise that there should be a change in the *manner of teaching* the mathematics. Too generally mathematics appears to the engineering student merely as a "chore," a subject to be "passed," or mental gymnastics prescribed by the learned faculty as exercise for developing the student's brains. The teacher of mathematics usually fails to give the student that inspiration and interest and sense of power and pleasure which come with a realization of the meaning and the utility of the mathematics. The student learns to go through the forms and motions of the science without ever entering into the spirit of it. He conceives the purpose to be that he shall learn how to deduce symbolic formulæ in which numerical values may be substituted for a, m, and x so that when he turns the crank the desired answer will be rapidly evolved. Rarely is he brought to understand that this mathematics is not merely a mysterious infernal machine but that it is a beautiful shorthand method for writing down and manipulating his own thoughts concerning the quantitative relations between real things.

Many students in courses of mathematics acquire a blind faith—a conviction—that a proof by mathematics is sufficient, and is final. They do not understand that this man-made invention merely expresses truth, and is not in itself the substance of truth.

Such blind faith in forms and conventions may lead to grievous errors—in engineering work if not in other lines. It is the beginning of the formula-habit which fetters the imagination and destroys the initiative—which is in effect a veritable hook-worm disease for the engineer. To the engineering type of mind it seems that an abstract thought passes the supreme test not when it merely harmonizes with other thoughts but rather when it becomes alive, in material or in action. We are certain of the futility and doubtful of the soundness of any mathematical knowledge which enables its possessor to work with generalities but leaves him helpless in face of the fact.

Regardless how many theorems he may know or how many propositions he may be able to trace back to axioms, that student has best caught the spirit of his mathematics, who is able to understand clearly whatever particular problem may be presented (whether it be proposed in words, in action, in materials, or in a situation,) who can select and manipulate quickly and unerringly such data as he requires, and who can demonstrate convincingly the results of his calculations. Many teachers of mathematics have acquired through instinct or training a dense ignorance or a kind of disdain for all practical applications of their science, and this disdainful ignorance is likely to be reflected in their teaching and to react unfortunately upon the training and the careers of all but the most able and the most mature students. Mathematicians who have such temperament should not be permitted to teach students of engineering; for in engineering, mathematics though necessary is merely a means to an end and should be taught as such, not as the end in itself. It seems to be a tradition among mathematicians that prestige and advancement may be won only by methods which tend to make of the ambitious professional a rather narrow and uninspiring specialist, and this is subversive of good teaching especially for immature minds which are not primarily interested in mathematics.

Whatever may be the amount of mathematics taught or the manner of presenting it, engineers agree that it should always be taught *thoroughly,* so that the student shall acquire a permanent

grasp of the science and shall be able to make use of it instantly on demand, easily, swiftly, and with some degree of pleasure or satisfaction. Whatever branch or part of mathematics he undertakes to learn, the student should be compelled to master it so that he uses it as readily as he should use arithmetic; mathematics half-learned or half-understood is not only useless but misleading. This does not necessarily require lengthening the mathematics courses, for most classes of students could be speeded up far beyond their present rate of progress if teachers would vitalize the courses of mathematics by showing the students how to throw their everyday problems into the mathematical form, how to interpret the results of mathematical processes in terms of ordinary phenomena, and how to accomplish by mathematics the solution of interesting problems which otherwise would seem unsolvable.

A large measure of responsibility for thorough training in mathematics undoubtedly rests with the teachers of engineering as well as with the teachers of mathematics. Even if the instruction in classes of mathematics were ideal, all but the extraordinary students would lose their grasp of the science if they were not constantly required to apply it in the regular work of classes in engineering and other subjects. While it is not advisable to use (for the sake of discipline) more mathematics or harder mathematics than is required to produce the desired results in the most efficient manner, nevertheless the teacher of applied science or of engineering should not avoid the use of mathematics where the use of it would economize time or effort, for in so doing he vitiates the previous mathematical training of his students and wastes their time. There should be coöperation and coördination of the courses in engineering with the courses in mathematics as with the courses in English, to the end that the development and discipline of the student shall be continuous and unremitting throughout the entire period of his college training.

Question 7a. How many actual hours per week do you think a student should be present in classes?

Typical answers, arranged approximately in the order of seniority of the writers, are as follows:

"Generally, it is safer to insist on a reasonable minimum of tasks being thoroughly done by each student. In short, something similar to the piece-work plan used in factories, except that in college the 'pieces' will not be alike. Beyond this, reliance should be placed on the Student Advisors of the Faculty."

"Eighteen hours, or the equivalent in laboratory on a 3:1 ratio."

"Twenty-eight to thirty hours per week, about equally divided between classroom work and laboratory periods, is a fair amount."

"About sixteen. Lectures are not nearly as good as recitations with casual lecturing to illustrate obscure points. Laboratory is excellent."

"Student should be present in class under the direction of instructors for from 37 to 44 hours per week."

"See my paper on 'Efficiency of Technical Education,' before Soc. Prom. Engg. Educ., June, 1912." (George H. Shepard.)

"I think 20 hours per week in class work and 15 to 18 hours in shop and laboratories about right."

"A student should be present in classes 24 hours per week: from 8 to 12, for six days. Vacant periods are sure to be wasted by the majority, spent in lounging about in idle gossip. Every hour should be laid out for him, as this is probably the condition he will be up against when he faces the world, and he may as well get used to it."

"This is so dependent upon age and temperament that a rule to fit average conditions could only be given by a close study."

"In classes about 30 hours a week. Vacant periods between classes usually wasted."

"School should be run like an office or workshop—with definite hours filled in full. When you get on the job there will be no vacant periods for seasoning or contemplation. . . . ."

"The student's time should be fully occupied during what would be normal business hours, say from 9 a. m. until 6 p. m. There should be no more intervals for him during that time than is usually accorded to any person engaged in business."

"Work student four hours in a. m. five days of week, three hours in p. m. and Saturday a. m., off on Saturday p. m. and Sunday. The three hours should be field, laboratory and design. Think the vacant hours are wasted; better be taken up in lectures for one hour in morning."

"Depends upon character of the subjects—whether lecture, lab, shop, or drawing-room, and also upon how much home work they require. Probably 2 or 3 hours daily in morning for recitations or lectures, with say 4 hours in afternoon for lab, drawing or shop, should not worry a student who is at all worth while."

"All hours should be filled."

Thirty hours per week should be sufficient, as I do believe in vacant periods. If all of the regular working hours are taken up in the classroom there is little chance and less inducement to season and follow up doubtful points by use of the library or visiting nearby practical examples of the question at issue."

"Not less than six hours per day for six days a week, and cut down to a minimum vacant periods between classes. He should be *trained* to work hard and continuously as soon as possible in preparation for his work after he leaves college."

"The results of study are best when students are pushed in their work. They should be kept busy all the time."

"Largely dependent upon the individual student."

"At least 55 hours of school work per week, including 25 hours in classroom and laboratory."

"In classes and laboratories about 39 hours a week: 7 hours a day for five days and Saturday morning."

"I think about 42 to 48 hours of class and laboratory work per week about right."

"Eighteen to twenty hours classwork per week. Ten to twelve hours shop, drawing or laboratory work, with more and stiffer laboratory work, emphasizing the importance of well-gotten-up laboratory reports."

"There is a decided advantage in any instruction if the classes are small and the instructor a man of such judgment and force that he directs both the laggard and the brilliant student to their best effort. There must be a variety of subjects taught if the training is to be well balanced, but periods given to a subject should be long enough to get well into the subject and even to bring the student to use his will to continue the work. My opinion is that the day's instruction and study should begin early in the morning and continue without interruption, except for luncheon, to completion. Time for athletics and diversion should follow. Intense application and sustained mental effort during the time given to the studies of the course and then complete change as the student may choose, physical exercise, music or social entertainment. In most cases, I believe evening study is a waste

of time. As learning is the student's business, the best part of the day should be used for it."

"Thirty-eight hours per week was too long for me to spend at the University. I didn't approve of the six-day schedule, which kept me up late at night working on reports, and often kept me busy all day Sunday catching up with back work. Perhaps I took it too seriously."

"Present in classes 30 hours per week."

"Forty-four hours."

"Twenty to thirty hours."

"Thirty hours at least."

"About 35 to 40 hours, including about 15 hours of drawing or shop or lab work, for which no particular previous study is required."

SUMMARY: All parts of question seven will be summarized together, after all the quotations have been given.

Question 7b. Are vacant periods between classes useful, or are they likely to be wasted? Is it valuable for students to have vacant periods for "seasoning" their work, or for contemplation; or would it be better to accustom the student to having every hour of the day laid out for him, and train him to do his thinking "on the run" as he works?

Typical answers as follows:

"Vacant periods are not useful; are unknown in practical life. . . . . May be all right for 10-20 per cent of the students, but not for large majority. For best results, by all means lay out all the hours for the student. Cooling down a furnace or kiln, or breaking training, are prejudicial to ultimate success."

"I believe the student should have some spare time during the day, rather for recreation than for study."

"Varies according to the nature of the work. Vacant periods are useful if proper provision is made where they may be utilized, much depending, of course, on the will or desire of the student and distracting influences. Not wise to have work crowded too closely."

"Vacant periods are likely to be wasted. It *would* be desirable to have periods for seasoning and contemplation, *if* the students would season and contemplate. For the first two years of an ordinary college course, it is better to have the students' work laid out so that they are busy all the time they ought to be working."

"The student should be trained to think quickly and accurately as he works."

"Vacant periods between classes are useful to some types of student, but otherwise wasted. Personally, I do not think much of them."

"I do not believe the majority of students are as such capable of 'thinking on the run' about subjects which they are just endeavoring to master. That is a condition which comes from development of thought and the broadening of knowledge. College can only form the foundation; so let it be made carefully, that afterward the superstructure may proceed much faster."

"Vacant periods are wasted in most cases. A student is an animal who can use no time to advantage 'contemplating.'"

"Too generally vacant periods between classes *are* wasted. I fear that most students do their thinking 'on the run.'"

"I always found vacant periods between classes useful."

"Vacant periods generally wasted. In general, the assignment of definite times for carrying out work produces better results than an indefinite allowance of time."

"Vacant periods seldom used to advantage. Intervals between classes in the same subject such as occur when a subject is only presented two or three times a week are objectionable in that they do not hold the attention of the student to the course in question. The student should be encouraged to make up his own daily and weekly schedule including proper amount of time for study, recreation and exercise, and the advantages of holding closely to such a schedule should be pointed out to him."

"Do not think the average college man uses much time for 'seasoning.' He is more likely to use it playing baseball, which although beneficial, should not be sandwiched in with study periods."

"Vacant periods between classes are not only a waste of the student's time for that period but are very likely to cause him to miss other classes."

"Vacant periods between classes may be utilized profitably if they occur at the proper times. A vacant period immediately before a hard recitation will be useful but following it may frequently be frittered away."

"Vacant periods between classes are unavoidable in many cases in the making out of students' schedules. Rightly used, they lessen the amount of night study. Students should be encouraged to make proper use of these odd moments. It might well be called the intensive use of time."

"Seven hours per day, five days per week. Vacant periods seem to me to be of little use, and are likely to be wasted. One cannot leave many kinds of work to be done in a definite number of minutes—a problem, for instance."

"I remember that I used to spend *single* vacant periods in light reading at the library."

"Vacant periods between classes are likely to be wasted but too long a succession of continuous hours is likely to be very tiring. I think that a student should be trained to think rapidly but without jumping at conclusions."

"I would have three class periods in succession preceded or followed by one free period. This would eliminate *'cramming'* in one period for the recitation in the next period. Have laboratory work during the first hours of the afternoon."

"Vacant periods are usually wasted, and the student gets the loafing habit. Real work seems very hard to the college graduate because he is required to do 44 to 55 hours per week, instead of 35 or less as in college. During football and baseball seasons the working time should be shortened so that the student may take part in athletic sports; and if he took no actual part in sports, he should be *compelled* to put this time in gymnasium work either in the gym or out of doors."

"Vacant periods *are* useful. If the student chooses to waste them, it is no proof that they are not useful."

"Vacant periods are useful even if apparently wasted. A student should learn to regulate his own affairs."

"Vacant periods are not good, as they are generally too short to be fully utilized. I think a schedule ought to be about as follows: 8-10 a. m., preparation; 10-12 a. m., recitation; 1-2 p. m., recitation; 2-5 p. m., shop or laboratory; 8-10 p. m., preparation. I believe students would get more good out of college if they would work hard 8 hours a day, instead of being compelled to work late in the evening to do considerably less work."

Question 7c. What are the relative values of "lecture," "recitation," and "laboratory" work, in your experience and observation?

Typical answers as follows:

"Recitation 10, laboratory 10, lecture 3. Life is a laboratory. Recitations and laboratory work should be coördinated. Lectures should be used only to supplement the best available textbook, for undergraduate classes; they are good for demonstration purposes and for graduate students."

"In teaching engineering, lectures are necessary and may be efficient, if coupled with suitable recitations and quizzes. In general, I do not think American students are mature enough to grasp the entire subject by the lecture system. Laboratory work may be valuable if properly conducted, but a great waste of time if improperly conducted."

"Recitations have much more value than lectures for the undergraduate student. The hours I spent on lecture notes might better have been spent on the track or in the gymnasium. I have never had any use for the lectures, and would have had for the muscle."

"Lectures are worse than worthless. I do not condemn explanations of difficult work nor talks of various kinds, but merely the system in which a *course* is taught by lecture, the student taking notes. I believe in recitations, particularly for the first two years, and in laboratory work selected with discrimination to develop or fix ideas but not carried to the extreme of teaching numerous simple facts and truths that can just as well be taken in by the mind in reading."

"Laboratory work should train the student to rely on his own initiative."

"In my experience most lectures are of doubtful value. Unfortunately most of my teachers either presented the subject in a dull, uninteresting way or presented so large a number of technical facts that it was impossible for the student to absorb them. In taking notes the student, being insufficiently trained in taking notes, is usually unable to take down more than a fraction of what is given and what he takes down is likely to contain many errors. . . . . On the other hand I consider it of great value to have a lecture about once a week by some practical successful engineer, provided such engineer is a man of strong

personality and is able to present his subject matter in an interesting way. . . . . Such men would have to be chosen with great care. Not every successful engineer would be qualified. For example I believe the late Alfred Noble would not be qualified to present such a lecture as I have in mind."

"Laboratory and shop are most valuable for the first two years, recitations equally so thereafter. The lecture I do not consider valuable at all."

"Problems are the best form of education; 'discussion' is better than recitation by rote; 'laboratory' and 'field work' are necessary, and 'lectures' are of least value as a regular thing but are invaluable if they arouse the interest of the student."

"Lectures, though least valuable, tend to develop in a man the ability to concentrate and to take in what he is hearing."

"The impression which remains in my mind in reference to lectures is that they were wasteful of the students' time on the whole. The demonstrations in lectures were nearly always of value. The requirement that a student take notes during the lectures is I believe now nearly obsolete; it certainly should be."

"Keeping in mind the age and previous experience of the students in our technical schools, I believe that recitations are most important, followed by laboratory or drawing-room work, and finally by lectures. Much, however, depends upon the subject and the personality of the man conducting the course."

"Lectures should be given in the laboratory with practical illustrations."

"Best work is done in small classes in which lecture and recitation work is interwoven in an informal way and in which the students may ask pertinent questions at any time without formality."

"This kind of comparison is, however, too much like asking which you would prefer to lose, your hand or your foot?"

"The lecture to be effective should be delivered slowly and the student should have read on the subject or otherwise acquainted himself with it. Lecture, recitation and laboratory work are interdependent, and should follow in the order stated."

"I consider lectures, laboratory work and recitation work of value and importance in the order given."

"Recitations, laboratory work, lectures."

"Lectures are principally useful for the purpose of presenting new viewpoints or newly discovered information which has not yet had an opportunity to become incorporated into textbooks *and for the purpose of arousing interest on the part of the students.* The real work of any course must be done in the recitations and laboratory work where the student is put upon his own resources and expected to think and act upon his own initiative."

"Lecture, recitation and laboratory work cannot be appraised on any common basis as they are all equally necessary for their specific purposes. Lectures, if used to augment the text where recitations are required over lecture notes, are quite as valuable as text recitations, while laboratory work where students are placed largely upon their own responsibility and the laboratory reports at least partially worked up under the direction of an instructor is of prime importance in familiarizing the student with the application of theory to various types of apparatus."

"Laboratory work, recitations, lectures."

"Recitations, laboratory work, lectures."

"Recitations is most instructive, a lecture next, and unless the instructor is skillful and not overworked laboratory work is least instructive per hour expended."

"Laboratory work in small groups in charge of an instructor seems to me to be the ideal system, with an occasional recitation or demonstration hour and frequent short examinations to take the place of the usual recitation. The amount of work or number of problems or experiments handled in the laboratory should be curtailed sufficiently to insure that none of it will be done superficially. The student should be examined to find out how extensive his knowledge of the subject is rather than how many facts, rules or formulae he may have committed to memory or how many lectures or laboratory periods he may have missed. This applies to all subjects."

"Lectures should be kept to a minimum and laboratory work to a maximum. A certain amount of recitation work is necessary in most subjects, but these should be conducted so as to cause the least loss of time to the student. For instance, thirty students in a class in mathematics should not be required to listen to the demonstration by the thirty-first of a problem that they all understand. I would only have demonstrated the problems that a number do not understand and want enlightenment on and would let the rest study tomorrow's assignment or anything they chose as long as they did not interfere with the class."

"Recitation, laboratory, lecture."

Students should not be allowed to take any notes during lecture but should be quizzed next day on the subject of the lecture in order to test the power of the student to concentrate and to remember what he has heard."

"Relative weights are: Lecture 1, recitation 2, laboratory 1.

"Lecture 20 per cent, recitation 50 per cent, laboratory 30 per cent.

"I found lectures of least value, with recitations and laboratory of about equal value."

"Relative values, lectures 49 per cent, laboratory work 49 per cent, recitation 2 per cent. Except in teaching mathematics and the like, the method of teaching by recitation is good only for children and students who do not want to learn. It seems like a waste of time for the 'live ones' to sit and listen while the professor tries to draw some ideas out of a bonehead."

"Laboratory work is the most *impressive*."

"I do not think highly of lectures; the student obtains information with so little effort on his part that very little is retained except in notebooks which are never used again. A judicious combination of laboratory work and recitation gives the student a grasp on the situation and fixes it in his memory and makes him feel that he is learning something that is more than mere abstract theory."

"In my experience nothing takes the place of a good searching recitation in which a man must give a reason for the 'faith that is in him.' Laboratory work should develop initiative and originality."

"Verbal class recitation is good once in a while, and should give confidence and speaking ability. Recitations in general should be written. Few teachers are able to bring out good discussions."

"Recitations, laboratory work, lectures.

"Lecture courses are most valuable, since a course of this nature puts the problem of getting all there is in the subject up to the student himself. Laboratory work likewise is very valuable, but I do not favor recitation work."

"Laboratory work is of greatest value, provided student is required to lean upon himself more than upon anyone else, and further is required to discuss laboratory experiments in the classroom. Lectures as a rule are not of much value unless upon intensely interesting subjects. Demonstrations help."

"The recitation method is much more efficient when properly conducted, than the lecture method; it can easily degenerate to the level of the lecture or lower, if the instructor does the reciting."

"There were three or four of us who frequently met to talk over some point that was not altogether clear or to solve some problem. I was surprised to find how different some look at a certain phase or how they started to attack a problem. I believe that these informal meetings helped me very much. Therefore I believe that for lecture courses it would be helpful to the students, as well as to the teachers, if after a certain number of lectures a period were devoted to review by discussion, in which the students as well as the lecturer partake, of the ground covered by the lectures."

"I think that the value of recitation periods is nil. We do not come to college to tell what we know, but to learn."

"Laboratory, recitation, lecture."

"Laboratory work is very important as it is astonishing to note how many men perfectly capable of consecutive reasoning are absolutely at a loss to apply such reasoning when they have placed upon them the responsibility of action. Roughly, I should say that lecture periods should take 50 per cent of the time, recitation 20 per cent and laboratory work 30 per cent."

"Lectures 2, recitation 2, laboratory 1."

"If it were possible, it would be well to have class or lecture periods crowded together and get the student into habits of sustained exertion. Moreover, it seems better for the student to be able to prepare himself for several subjects, training him to retain a grasp of varied ideas over periods of interruption. Too many vacant periods are apt to develop a hand-to-mouth method of study."

"Recitation 50 per cent, lecture 25 per cent, laboratory work 25 per cent."

"I believe vacant periods between recitations are valuable, either for study or rest. These periods give a chance for a change of viewpoint between radically different classes, and best of all, a healthy interchange of ideas among the students that often brings out the subject matter more clearly than the instructor does. In recitations, get around the class daily, if possible, and not in alphabetical order. Recitations and written examinations should come often enough to eliminate stage fright."

"Recitation, lab, lecture."

"In general, I believe a student as well as an engineer in practice is happier and more efficient when working at full speed, provided he is not so busy as to feel himself hounded. In my case, vacant periods between classes were either wasted or devoted to cramming for a quiz, a variety of study which I now know to be of no permanent value. In after years a man must learn to work steadily and to do his thinking as he goes; why not get into the habit in college?"

"It is the lecturer and not the lecture which is valuable. We all of us (4) got more out of our recitations when they were in the morning, and when the whole afternoon was left free for shop or laboratory work or study."

"Lectures: recitations: laboratory:: absorption: organization: application. I believe that all three are necessary.

"Overwork in laboratory, with attendant reports and drawings, tends to obscure the basic facts in the mind of the student."

"Recitation, laboratory, lectures."

"Recitation 50, laboratory 40, lecture 20."

"Chemistry and Physics manifestly need a larger amount of laboratory work than some other subjects. A straight lecture course without recitations is bad. . . . . On the other hand, some subjects should have more lecture work than they are usually given—for example mathematics, which seems to be taught as if it were only a course of mental gymnastics. A lecture per week in Calculus would serve to couple up the theory with some of the everyday phenomena of life in a way which never dawns on the average student."

"Laboratory, recitation, lecture. . . . . The *manner* in which the student works should be watched."

"Lecture, recitation, laboratory."

"Recitation, laboratory, lecture. Vacant periods likely to be wasted—'bunch your hits.' "

"Recitation, laboratory, lecture. . . . . As financial considerations usually require larger classes, simple problems bringing out principal points should be *handed in daily*. I believe that the student who lags from day to day and then just slides through at the end of the semester is the most dangerous product of any school. Laboratory work is excellent for fixing principles in mind; the write-up and deductions are the most valuable part. . . . . If the purpose of lectures is for training in listening and note-taking it would be better to have some on subjects of general interest."

"Recitation, laboratory, lecture."

"The greatest good I received was from a combination of recitation and laboratory where the instructor asked frequent questions involving the relation between the principles given in the lectures and the work being done at the time in the laboratory."

"My highest grades were in subjects in which I very seldom if ever even reviewed before examination. A man trained to do his 'thinking on the run' would have an unlimited supply of 'horse sense' in the end. Lectures might induce a man to think, provided he was interested in the subject; recitations make him think and laboratory work proves to himself what he thinks he knows."

"Lecture 1 per cent; recitation 15 per cent; laboratory 25 per cent; study at home 59 per cent."

"Relative values of lecture, recitation and laboratory work are as 2 : 3 : 1 . . . . Ability to express oneself orally on a subject is the most severe of criteria. Moreover, the student under 'quiz' is more or less in the position of the engineer under consultation, and to that extent the student is under training for his future work. The recitation may well be the means of reporting upon personal observation, research or outside reading, as well as a discussion of the lecture material."

"Lack of real sincerity on the part of the student is the cause of nearly all dissatisfaction with the course as it is given. Nearly any way of presenting the material will do the man who cares, and it is wasted effort on the man who does not."

"All engineering students should be encouraged in taking summer positions as it gives them a chance to try several lines of work so that when they get out they will not waste time in some field which they do not care to follow. It gives them an idea of how things are done."

SUMMARY: When we try to crystallize this mass of opinions concerning the proper duration and lay-out of the students' working day, a difficulty is introduced by the fact that few correspondents state whether the figures they propose include hours of preparation outside of hours in class, or only the hours to be spent under direct supervision of an instructor. The average of all specific recommendations, including many not quoted, seems to be

about 33 hours per week, comprising 18 hours of recitations and lectures, with about 15 hours in the laboratories, shops, and drafting rooms. Presumably these are the hours that should be spent under instruction at the college, and do not include hours spent in preparation for class work or in doing such work as report-writing which may be required to be done outside of the laboratories.

Many alumni contend that the student's working day should be at least as long, as continuous, and as strenuous as the ordinary business man's day. The author is one of those who hold such opinion. The high school and college periods include the most valuable years of a young man's life, on account of the freshness, impressionableness and mobility of his mind at this age, and of the opportunities offered through the associations open to him at school. Making the very greatest possible use of this time should be, therefore, the student's serious business as well as his chief personal concern and interest. Any young man of this age and state of education should be able to understand that his attendance and work at college is not solely and merely to please his parents or to establish a place for him in society or to increase his capacity to earn money above what it might be if he did not go to college, but that every moment of time and every bit of energy which he expends seriously in the pursuit of collegiate ideals is invested in his own *self,* and that the capital which he can thus establish in brain-power, in breadth, sympathy and vision, and in character, will be more durable and will ultimately yield him enormously greater dividends of contentment, happiness and pleasure than any mere hoard of money or passing pleasure which he might lay up by devoting himself to less substantial occupations. In short, as the college student is working for himself, he should be eager to work to his maximum capacity.

Besides making the best use of an exceedingly valuable opportunity, other advantages result from having the student's working day as full as may be without reducing his time for recreation and for purely social and non-scholastic activities beyond the desirable minimum. Thus, he develops habits or qualities of industry,

concentration and endurance which facilitate the inevitable transition from college life to business life, and which are essential to success in business enterprise. Futher, it is the experience of most men that their best results are achieved by working under pressure —not the pressure of a hopeless mountain of accumulated duties, but rather the steady insistent pressure of a routine of work which habituates one to the satisfaction of accomplishment and to the periodic pleasure of having completely finished the task.

With these considerations in mind it is reasonable to entertain the suggestions proposed by the extremists among us, namely, that the student devote full eight or ten hours per day to college work including study—a total of 44 or 55 hours per week. While mental work is more strenuous than routine business, it offers relief through variety, and the element of nervous stress through serious responsibility is lacking also. If we take an average figure of 50 hours per week, so as not to bear too heavily upon the slow student, we find that about 17 hours of study should be had outside of classes, or about one hour of preparation for each of the 18 hours of recitation. This would give us, for each of five days in the week, three hours in the classroom, three hours in laboratory, shop, or drafting-room, and three hours preparation or independent study; on Saturday, only three hours in the classroom and three hours study. Thus there should be ample time for proper recreation, social intercourse and rest each day, without encroaching upon Sunday.

The question now arises, *when* and *where* shall the student do his independent studying—in occasional or casual vacant hours between classes or in a single long period each day,—in college buildings under observation and influence of instructors, or in his home or elsewhere without supervision? The problem of the vacant hour has been discussed quite fully through the questionnaire; but upon the latter point, the writer has only his own opinion to offer.

On the whole, an unmistakable majority of our correspondents believe that the vacant period between classes is waste time. Arguments against it are that it breaks the continuity of thought,

and of interest in the work, which are important factors of student efficiency; that it weakens the powers of concentration and endurance, and makes a student "flabby"; that it fosters habits of idling, cramming or superficial study, and desultory reading or thinking; and that it is frequently a cause for failure to attend subsequent classes. Arguments in favor of the vacant period are, that it may promote discussions among the students which should benefit them; that it furnishes opportunity, if not incentive, for independent study and thought; that it trains a man to consider the utilization of his spare time, and promotes self-control; and that it gives valuable opportunity for recreation as relief from mental exertion which might otherwise be too continuous for highest efficiency.

The utility of vacant periods, even while doubtful, depends upon their duration and location, and upon the means and incentive which are provided to use them to advantage. Single hours are in reality seldom used efficiently because of mental inertia and lack of self-control, however desirable it may be to develop the ability to use them. The sequence of class periods and vacant periods is seldom as it should be in order to promote effective use of the latter. While usually meagre facilities are furnished for idling, and reading-rooms and libraries are usually made comfortable and atractive, yet the student is not often brought to feel the pleasure and profit to be had from the latter, early enough to induce a habit of using them at every opportunity.

Altogether it would appear that the use of vacant periods, as a factor of character formation and of student efficiency, has received much less study by administrators and program designers than its real importance warrants, and that we have in it a great opportunity to improve engineering education. Obviously, if we contemplate prescribing or supervising the manner in which all vacant periods or study hours shall be used by the student—that is, compelling him to spend nearly or fully fifty hours per week under the eyes of instructors, then either the cost of college education must increase or college teachers must work longer hours. If the teachers were chosen in consideration of their interest and

enthusiasm in the work of teaching, and if they would study more generally and deeply the efficiency of their teaching, it might develop that these longer hours need not be a hardship—especially so in the case of those who teach the fundamental and more formal courses. The conscientious student under such conditions should feel benefited by having his teachers at call for the longer period and by having his time for recreation bunched so as to permit real relaxation, while the dilettante student would perforce become more diligent.

Opinions concerning the relative values of lecture, recitation and laboratory work have been quoted very fully because they are instructive and because there is nothing approaching unanimity in them. While each of these vehicles of instruction receives some adverse criticism, it may be said that in general the apparent fault is traceable to abuse of a good idea, or to misunderstanding of the real purpose. Lack of vision, also, is responsible for certain inconsistencies, as of critics who complain of wasting time in writing up lecture notes almost in the same breath that they deplore the insufficiency of training in use of English language.

In general, it appears that courses of any kind have been valuable in proportion to the amount of independent brain work which they required the student to do. Perhaps this is the reason why recitation work is clearly preferred. There is also a significant demand for closer and better coördination of lectures and classroom work with laboratory work. Particularizing, first with respect to lectures, we find that their value depends primarily upon the personality and address of the lecturer himself, rather than upon the subject of the lectures. Lectures are worse than valueless if they do not inspire interest and enthusiasm in the students. Lectures should be delivered slowly, should not be taken up with mere statements of fact, and should contain some demonstrations or illustrations but not enough to prevent the lecturer from giving and the student from receiving a sequence of thoughts. The value of lectures resides to some extent in habits of concentration and attention to which the student may be trained thereby, and in the new and unpublished information that may be

presented or in the vitalizing of the subject matter. Care must always be exercised that the real values of the lecture be not lost through taking too copious notes; yet the active interest of the student should be assured by giving searching quizzes upon the subject of the lecture.

Laboratory work, to some types of mind, is more impressive and long remembered than any other kind of instruction. However, its value is quite generally impaired by certain typical abuses which may cause great waste of time. While anything undertaken should be done thoroughly, on account of character training if not of the subject itself, time is not economized by demonstrating experimentally phenomena or relations which the student can reason out conclusively to his own satisfaction, nor in requiring the engineering student to do much of merely mechanical or routine work which may smother his thoughts or curtail his interest and initiative. Best results seem to be attained when the instructor does some lecturing or quizzing on the laboratory work, and when the reports are prepared under the supervision of the instructor. Properly administered, laboratory work should develop in the student the ability to translate his thoughts into actions, either independently or in coöperation with his fellow students.

Recitations, if conducted in the interest of the greatest number of students or at least of the average man rather than merely for the benefit of the most stupid or lazy ones, are the most effective arms of the teacher. However, there seems to be quite generally a misunderstanding or lack of appreciation of the functions and possibilities of the recitation. It should be not merely a period for rehearsing that which has been learned, but more an opportunity for the students to discuss informally among themselves and with the instructor the difficulties which they have in common and which each individual has previously fought with manfully but failed to conquer. It should be an opportunity not merely for the instructor to discover what the student knows or does not know, but rather for the student to notice the faults in his own mental processes and to learn how the trained mind of his instructor thinks. The classroom discussions should give to both instruc-

tor and students the advantage of new viewpoints, and to the latter particularly self-confidence and speaking ability. Occasions should be provided frequently for the students to question the instructor; the latter is too likely to forget the natural hesitancy of the former in asking questions about what is not clear, and to monoplize the time with his own talking particularly as he becomes older and more experienced. To fulfill their functions of checking up the students' work and of enforcing discipline, recitations should follow and cover the lectures or study assignments regularly, promptly and rigorously, and the system adopted should not permit any student to make special preparations or to enjoy special immunities.

Question 6a. Do you think that too much, or too little ground is covered by the college course?

Typical answers arranged in order of seniority approximately:

"Today there is too great a tendency toward specialization at the sacrifice of thorough fundamental training."

"Too little ground covered."

"Too much ground covered."

"Too little attention to English work. Time lost in modern language. Course was weak in not giving enough of steam engines and machine design to civil engineering students. Electrical engineering was almost unknown at that time (1880-1884)."

"United States Naval Academy course (1891) could have been improved by more shopwork, better taught."

"I think that too little ground was covered by my course of twenty years ago and that I did not work hard enough, or in other words while I put in time enough, my time was not spent to the best advantage. As it was I took a four-year course in three years and graduated at the head of my class. I am very positive in believing that this was not due to exceptional qualifications on my part. I believe that with proper organization of the courses and proper coöperation among the faculty many others in the class could have done the same thing, could have covered the ground in three years, and when graduated would have been better equipped to take up engineering work than was the case. It is my belief that too much time was wasted on dull, abstruse, uninteresting lectures, that the mathematics were unnecessarily hard because the students had not been sufficiently well grounded in the rudiments of mathematics and because the interest of the students in theoretical subjects was not sufficiently maintained."

"The state law concerning the Agricultural College (Michigan) required that graduates from the eighth grade be taken and turned out college graduates in four years—an impossible undertaking. Given the conditions as they were, it would have been better to cover less ground more thoroughly. However, there were some very important things omitted such as History, Biography, Economics, Natural Science, Arts." (From graduate of 1893.)

"I should say that my curriculum was fairly well balanced but do believe I could have obtained more real benefit if I had been given a truer conception of what would be required later. I did not have to work too hard yet would not advocate cramming a course to the extent that a student would be required to study every minute of his spare time. There are so many things to be learned in college that the young man should be given time to weigh and adjust his learning. I would not add more to the classic for the engineering course but would like to see more time given in off hours to study of current engineering literature and visiting as many and varied industries as time would permit. It would not be necessary to take long and expensive trips as there are many examples of everyday engineering near at hand to most engineering colleges where, if the instructor were of the right sort, many things of importance and worth could be pointed out

to the student which he 'never noticed before.' Then again, lectures or talks by men who are doing things given in their own way would greatly assist in broadening the student mind. These talks should not be confined to great men for often their discourse is out of the ordinary sphere of comprehension." (This also is from a graduate of Michigan Agricultural College, class 1896.)

"Course given at Lehigh University to students in Mechanical Engineering was an exceedingly good one (1892-96). A technical student should look upon his college course as only the beginning of his studies; what he should get is fundamental principles upon which to build later his life specialties."

"Too little ground was covered in my college course when measured in subject matter although too much time was devoted to the curriculum itself."

"It is hard to say whether too much or too little ground was covered by the college course as the engineering profession is in continual development and to my mind a college training simply teaches the student to use his mind intelligently and correctly. In other words, it is very seldom that the theories or problems as taught in the college classroom are actually used in engineering practice in the form in which they are presented in the classroom. . . . . I believe that the course covered should be fully assimilated by the student since a smattering of any subject is not training or education whatsoever. In fact, such a smattering is quite likely to be harmful rather than helpful."

"I have very little if any criticism to make on my college course. Now that I am engaged in teaching I see many things in a different light than I did while practising my profession. It is an easy matter to criticise college courses but it is not so easy to suggest improvements."

"No man, while in college, can tell what his line will be in the future. A student should have enough knowledge of all branches of engineering to study up intelligently any given branch later on."

"There seemed to be a little too much work toward the end. There were too many reports and drawings called for."

"If I had it to do over again, I might spend less time on engineering subjects."

"Too little ground was covered, but I do not see how the number of subjects could have been reduced nor less time devoted to these subjects without making the matter worse. You will probably infer, correctly too, that I believe the usual four-year course too short for engineers. In my course in Electrical Engineering we had mathematics through calculus but should have had also hyperbolic functions and a course on complex imaginaries; we should have had in the theory of alternating currents a study of the practical applications of higher mathematics which would have left us with sound working knowledge instead of a jumble of unworkable theory."

"Possibly too much ground to assimilate all."

"Some of that which I learned I could well be without—but a student cannot foresee his future career and needs."

"Too much ground covered, and too much detail work required."

SUMMARY: All parts of *Question 6* will be summarized together at the end of it.

Question 6b. Did you have to work (in college) too hard, or not hard enough?

"We were compelled to work hard, but I have never regretted the habits of concentration and industry that had to be acquired to graduate, and I think there is a tendency nowadays to let up entirely too much upon students."

"Worked too hard. Too many subjects covered. Work repeated in allied courses."

"I think that the student entering a professional school should realize that he is engaging in his life's work, and that he has really commenced his business career, that it is work, and not play, and that the same application and energy is required, perhaps more than if he were employed in a subordinate position in any business."

"Those men in my class who felt they worked too hard were usually the shirkers, and the men who objected to doing anything that looked like work."

"It does not seem to me a question of having worked too hard or not hard enough, since it should be expected that all of the time should be occupied in any case. It is simply a question of how the time had best be divided."

"In my own course at Worcester Polytechnic Institute I believe the work was too hard to be of greatest value to the average student although I do not believe this to be the case in the average middle western technical school."

"I did not have to work hard enough."

"I had about the right amount of work to do, but I did not work efficiently."

"The work in college was hard, perhaps harder and with longer hours than is likely to be met in the ordinary business of after life. The training, however, is good as showing what one *can* do if necessary. I am well satisfied with my course."

"The average student *will not* work too hard, but would be obliged to if all work outlined were fully and conscientiously accomplished."

"Not overworked, and do not believe that any student should be. No man has a right to neglect his social and physical development for *any* other training; both are as vital to his future personal happiness and financial success as his technical training."

"Not hard enough, as I see it now."

Question 6c. Would it have been better, as you see it now, to cover fewer subjects more thoroughly or more subjects less thoroughly?

"Any subject of real importance should be treated thoroughly insofar as foundation work is concerned. Thoroughness in superstructure work may take up time better devoted to foundation work in other directions."

"I feel that minute attention to detail work along many independent lines of study is a bad thing for an engineering student. The lack of perspective is a serious one."

"We certainly were given a large amount of work to do, a great deal of it hard grinding, like the working out of forty or fifty problems in several subjects every day. In most cases no practical connection was pointed out between the problems and the work of an engineer and I believe that the majority of the problems could have been discarded in favor of such as would instil and fix a theory at the same time that they flavored of practical utility. In my own case I took extra work outside the course as I found time for it."

"As a rule, few subjects should be given at one time and they should be allied to one another."

"If anything, it would have been better to cover fewer subjects and to have put more time upon them, and I think that most of the time spent on elective courses on applications, even engineering applications, was time wasted."

"I think more subjects could be covered more thoroughly; in other words, I think the efficiency of college education is about 33⅓ per cent of what it should be."

"Less ground should be covered in each subject, and that part taught more thoroughly."

"Some senior work is beyond the grasp of the student and should be deferred until he has had practical work."

"I believe a few subjects should be covered with utmost thoroughness, but that they should be supplemented with quite a variety of other subjects, which should be arranged properly to give a student a general view of the profession as a whole; and such subjects do not necessarily imply any great amount of work."

"Too much. We had to work too hard to be thorough. It was a case of how much we could cram into our brains—not how much we assimilated and made ours permanently. It would have been better to cover fewer subjects more thoroughly. Lack of coördination was a grave defect, as well as lack of wise emphasis. There was no emphasis except that placed by each professor on *his own department.*"

"There was a lack of coördination in the courses. Mathematics should combine with designing and drawing, and produce results in the shop. We studied a subject and forgot it as fast as we had passed it up. The use of good English and of proper business forms should be demanded in the regular work."

"In my mingling with the other students, I found that the majority did not realize the benefits of their education and seldom 'got busy' until the fourth year. To a certain extent I would blame the instructors for this, or at least the board of control. It is very essential that some method be pursued which will impress upon the student the value of the time he is putting in at the University. The majority do not get 50 per cent of the training and education they should in the four years they put in."

"My course at Stevens Institute was well balanced with the exception, perhaps, that the amount of work to be done was apparently arranged like a pyramid, the base being the freshman year, when a great deal of work had to be accomplished. Less was done in the sophomore year and it appeared to me that things were made easier in the junior year and still lighter work was required in the senior year. This, however, may have been more apparent than actual. Possibly the requirements in the early part of the course developed not only a habit of work but also a greater capacity for it, but on that account, if I should have had

to suggest to the Board of Trustees of the Institute at the time I graduated what improvements I would make in the course if I had the responsibility, I should have said: 'Place a greater burden upon the juniors and seniors.' Very possibly this change has been made. I am not making any criticism of the curriculum at the present time because I have not sufficient knowledge to pass fair judgment."

"While I am not in favor of more hours, more work can be done in the hours already set."

"Some automatic check should have been provided for those 'profs' who took the attitude that their course was the most important and who assigned lessons about three times as heavy as the course's credit warranted. This often overloaded us unless we neglected some other study—otherwise the amount of work required seemed reasonably satisfactory."

"If anything cover more subjects less thoroughly; a good student will get more out of the course on account of the broader field while the poor student will only slide through anyway no matter how much or how little he has to cover."

"The college is a good place to learn to keep busy and do things in the shortest possible time."

"In the second year I did considerable outside work, so that with the exception of an hour on Tuesdays and Thursdays and Saturday afternoons, I had all of my time scheduled for six days a week from 7 a. m. to 9 p. m.;—after this experience, the regular college work seemed comparatively easy."

"Plenty of work develops habits of industry and I doubt if many college men are hurt by overwork in a regular curriculum. The fundamental subjects physics, mathematics and chemistry, should be so well driven home, in so far as they are carried, that they become working material and their use is a matter of ease and convenience rather than a painful effort."

"In my opinion there isn't one teacher in ten who is naturally born to teach. As a result nine courses, I believe, suffer."

"I think that the average engineering student enters upon his technical course with poor preparation, especially in mathematics."

"In a four-year course entrance conditions should not be allowed—the time they occupy is too valuable. English, algebra and trigonometry should all be done in the high school."

"Debate (extemporaneous and prepared), should be given more attention—it is valuable. I refer to the presentation of arguments in speaking before a class, a division or the school."

"I have no criticism of the amount of work in my course, in spite of the general feeling of my classmates that it was too hard. By this statement I do not wish to lay myself open to the charge of being exceptionally brilliant—I think the difference was due entirely to the method of study. I concentrated on principles and allowed applications to take care of themselves. In mathematics, for example, instead of working out all problems in advance so as to be prepared to demonstrate any of them in class, I contented myself with getting a firm grasp on the fundamental ideas of the day's lesson and took a chance on being able to apply those ideas properly to any problem that might be handed me. The amount of time spent for preparation was considerably lessened and the training, in my opinion, infinitely more useful. It seems to me it would be better if our college teachers would follow the example of our friend the porpoise and come up for air once in a while, spending more time in teaching their students how to study, even if it meant less time devoted to the details of their own specialty."

"I worked too hard, but not with sufficient intensity."

"I found that I did the best work during a year when my schedule contained not over two vacant hours per week."

"Too much ground was covered in my college course or rather too much text matter. I worked too hard for the information derived from my efforts."

"The last year we didn't do anything very thoroughly, as I remember it, but we covered a great deal of ground and in that way got a little insight into the nature of various civil engineering activities, which will possibly help us to choose our line of business if we ever get a chance."

"If special emphasis were placed on getting men through their first year, and letting them start the second year without any conditions, most men would get through easily unless they were very weak in mathematics."

"Didn't have to work too hard, but did. Haven't worked so hard since. Courses are about right now, if the student is not influenced too strongly to try for a perfect mark."

"I did suffer from unwise emphasis in a great deal of the course and we shall all do so till we take our teachers from the field. Only men who have put the theory to practise can know what points to emphasize."

"Higher standards of grading, requiring more careful work on my part, would have been a good thing for me."

"College is or should be a business proposition; if the student can't see it that way he shouldn't be there, for he holds back those who want to work. Eight

hours a day—not necessarily all class or laboratory time, but trips of inspection to desirable plants are diverting as well as instructive. Go slow enough so that the man who has it in him, but is slow, gets a chance, but no favors for the man who is there to have a good time or an easy one."

"Had to work too hard; cannot now look back upon my university career with any degree of pleasure. . . . . The fellow who goes to a university and does not want to work hard enough to get along, should be promptly 'let out,' and thus not impede others. Conditions should not be made for the pupil who has to be coached continually."

"Too little ground was thoroughly covered, and perhaps too much effort was used in unsuccessfully trying to cover it. . . . . More rigorous thoroughness should have been insisted upon, and fewer ramifications of subjects considered. For instance, a very few sample, or typical, problems might have been given in each subject, the correct understanding and solution of which was strictly required for passing."

"There was, however, a lack of coöperation between the Engineering Department and the other departments; as for instance between the Physics Department and the adaptation of the physical principles to the engineering problem. One criticism in particular is to be levelled at the voluminous written report work demanded in the physics laboratory courses, as well as in the testing laboratory courses. This involved long discussions of the minutia of the tests or experiments, complete quotations from numerous references, photographs of the experimental specimens, and elaborately colored data sheets and curves. While of considerable interest and of certain value, they occupied time which might be better spent in other more valuable, if less artistic, efforts."

"Too little because the class had to wait for the dumb and slow ones who wanted to stay in school to have a good time. No student has to work too hard to get his work if he is interested."

"If as much effort had been spent on teaching the students as was put on marking and testing their knowledge, time would have been better utilized, at least by the earnest students."

"More attention should have been given to English, including at least two years of theme-writing, and criticism of all written work during the remaining two years."

"We had to 'dig' too hard usually, so that not enough time was given us to develop the social side of life and to meet the fellows outside of classroom. I believe more time should be devoted to seminar, and to general gatherings. However, at these times all the students should be required to take part and learn to address audiences, and to present technical papers and make offhand speeches."

Question 6d. Did you suffer from lack of coördination of courses, too much subdivision of subjects, repetitions or omissions, unwise emphasis, etc.?

"I suffered both from repetition and omission. For example, I had elementary mechanics in physics, again as a separate subject, and again in Applied Mechanics. Mechanics of Materials was not taught, and much of the drawing was useless. Many deficiencies I might mention would be of no interest now since I am speaking of 20 years ago, and they have no doubt been remedied."

"I am sure that I covered a whole lot of ground in my college course that didn't stick—like the plaster on a cement house that comes off. Why? Because I took the work just to get the credit. After I had stopped out for a year—got a technical job and went to work—afterwards, returned to finish my course with a definite purpose and a decided 'want' for a better training—then I did more 'hard work' in an easier way than in all my previous course. After I knew what I wanted I didn't suffer from repetitions, omissions, or unwise emphasis, that the wanderer is subject to.

"Repetitions are good when wisely used; courses should overlap one another. Unwise emphasis indicates lack of understanding of pedagogical principles.

"There was lack of coördination of courses in some respects, particularly between the courses in mathematics and the time devoted in the courses of physics to mechanics, and between the courses in physics and those in electrical engineering."

"But in order to have the subjects properly coördinated, all should be subject to the supervision of some one person, possibly the head of the engineering school. In fact, it might seem advisable to have the details of all courses given engineering students subject to revision by the head of the engineering school. By this method much work now given the students could be eliminated without sacrificing the essentials. In some subjects (for instance physics) it seems to

me that students are frequently made to take a great amount of inconsequential matter to get a little really essential knowledge."

"To my mind all branches of mathematics should be taught as a single course rather than have a sharp line of demarkation between them. I also believe that the greater portion of theoretical mechanics could well be combined with the calculus. The line of demarkation between physics and mechanics should be smoothed off. On the whole, the subjects are not coördinated as they should be and the student does not get the correct impression of the relation between the various subjects.

"Physics, chemistry and geology, as they were taught to me at the University, are very impractical courses. I remember in the high school I had a great liking for these studies, but when I began to study them at the University, I got the impression that I was studying an entirely different subject and all interest disappeared, and was not regained during the course. This indicates to me that something was wrong, and I believe it was because I didn't understand. I hadn't time to digest the knowledge that was imparted to me. In all these subjects we had lectures several times per week. The time spent at these lectures was almost a dead loss to me. The lecturer hurried through a scheduled amount of talk and demonstrative experiments. If you tried to take in what he said, you couldn't take down notes, and if you didn't take down notes you couldn't remember what he said for future reference. Furthermore, the lecturers seem to make a special attempt to state the facts in language not comparable with the language of textbooks, thus confusing the student still further. My idea would be to abandon the lectures on these subjects, except perhaps an occasional lecture on general features and on the relation of the subject to other branches of knowledge."

"I think, however, that some saving might be made by consolidating the mathematics courses. I would consider that anyone who was unable to go faster in these courses was not fit to be an engineer; and to cover the same ground with a class of men who could keep up would require perhaps only two-thirds as much time."

"Would suggest putting the time spent in physics on mechanical theory of heat, as applied to steam and gases, and electricity and magnetism, on the front end of courses in steam and electrical engineering if possible. We largely lost sight of them in the time between physics and steam and electrical engineering.

"We had freshman drawing fifteen hours per week first semester, and six hours per week second semester, on descriptive geometry problems. Too much time devoted to this. Machine design drawing in sophomore year could have combined practise in drafting with machine designing, and cut out some of the practise in freshman year."

SUMMARY: As stated in relation to a previous question, it is fairly well agreed that inasmuch as college work is the student's own business and concern, of which he is the beneficiary, he should work cheerfully as hard as may be necessary to obtain the greatest possible permanent return from his time and effort. Very early in his college career the student should be convinced by his instructors that it pays and is enjoyable to do real hard manful work which taxes his ability and endurance. While it is possible that some conscientious but immature students may spend so much time in going through the motions of working that they do not assimilate the essential principles of what they do, nevertheless it is certain that the usual inefficiency of the common garden variety of student is not due to this cause, for he is equipped by nature with a very effective and reliable safety-valve, and he simply *will not* work too hard. Rather, his inefficiency is due to lack of purpose, necessity or responsibility, to inadequate prepara-

tion in the prerequisite studies, and to numerous diversions which have no educational value.

To relieve the situation as much as possible, at the very beginning instructors should teach their students how to study and how to know when they really understand, how to observe, ask questions, and work intensively, so that greater output shall be achieved not by putting in more hours but by getting more out of each hour. While the dilettantes and the defectives should be weeded out as soon as they can be located, in justice to the genuine students, yet many who might otherwise drop into the former category may be saved if conscientious and individual effort from the instructors can assist them through the first year; because many students who manage to enter college have never received proper training of mind or of character in their homes or in the public schools and high schools.

Quite generally the opinion prevails that college education, like primary and secondary education, tends to run to fads. Few engineering schools are not in a fever to possess for their staffs without serious regard for his interest in and qualifications for teaching work, the eminent practitioner or specialist who shall add renown and draw students, by offering highly technical and specialized professional courses beside which the most substantial and vital courses of fundamental principles pale into insignificance. Few universities have not had distempers of special curricula and eruptions of weird degrees.

Whether it be a cause or an effect, the fact is that the student is required or permitted all the time to dabble superficially into too many and varied subjects, which have no apparent connection with one another or a too immediate connection with his sporadic and uncertain objectives. He should not be permitted the false and dangerous self-confidence which may proceed from a smattering; to insure thorough assimilation, he should at any time be studying no more than a few clearly allied subjects, and this he should do thoroughly in the sense that he concentrates his attention upon the fundamental principles themselves rather than upon the technique of their application in numerous and varied phases.

Applicational or practical courses have slight value as education, but may have sufficient inspirational value to warrant their use in small amount; although undoubtedly a better scheme to accomplish the same purpose would be to freshen the fundamental and theoretical courses by a sprinkling of the applications.

The student would profit permanently by any requirement which would induce him to acquire and enjoy the habit of reading and discussing the current literature of engineering, as in a seminar course where the whole class takes part. As college training is the foundation upon which a man's serious life work is begun, it should be as broad and as deep as possible; but many students have found the basic principles obscured by an excessive requirement of mechanical routine and minute detail in laboratory reports and drawings.

Lack of coördination between courses of instruction and lack of coöperation between teachers are general and serious defects of higher technical education. When each instructor is absorbed in a hobby or specialty, as a research man or as a practitioner rather than as a devoted teacher, it is needless to wonder why there exists between one fundamental course and another, or between fundamental courses and applicational courses, an undefined and uncharted no-man's land which must be jumped over or explored by the student unaided, unless he is to consider the courses to be really unrelated.

Even when the mathematics courses are coördinated among themselves, there is seldom or never much reciprocity or active interchange of thought and material between them and the courses of physical science or of applied science. While engineering science is really little else than physics and chemistry applied to useful purposes, yet for any perceptible diffusion of atmosphere among them, one might think them infinitely or eternally apart. The instructor of engineering must admit, even if he does not perceive, that his students speak and write wretchedly, yet he seldom exerts himself to discover or point out their errors so as to augment the resources of the department of English.

It is fruitless to argue that instructors of mathematics, of physics or of English should be engineers: even if men could be found with such catholic interests and abilities, the incentives to work in these various fields are, in the present and traditional state of ideals and organization, so diverse that such men must shortly become distinctly either physicists or engineers or rhetoricians. It is entirely practicable, however, for men of these various specialized interests to recognize that each has some interest in and dependence upon the others, but also to know that acknowledgment of this dependence does not signify complete surrender or abandonment to proselytization. If each of these teachers would make himself well enough acquainted with the work of the others to enable him to render effectively just that kind and degree of assistance which is needed, we should find fewer students who fail while having within themselves all the ability and information required, lacking only an appreciation of the availability of their knowledge, and its relations. Furthermore, when subjects and courses are carefully and obviously correlated, there is less likelihood that students will forget them as soon as the pressure is relieved by "passing" or "finishing" them.

In the organization and conduct of almost all courses there is much opportunity to make improvements which should shorten the time required to achieve the same or better results. To economize time, teachers must study how to "kill several birds with one stone." Simple speech, homely simile, and forceful directness, rather than grandiloquent formalities, are the weapons that will carry ideas through a student's cranium; he is inured to speeches and preachments, and quite able to distinguish the wheat from the chaff. Then too, as a natural consequence of being themselves self-centered, teachers fall to warring among themselves for the students' time, trying to see who can monopolize most of it by showing the greatest presumption or making the direst threats. Altogether the student's effort is seldom well distributed, either as between the several years of his entire course or as between the several courses of any single year or semester; and commonly the sophomore year brings courses which the student is

not matured or experienced enough to appreciate and which might be given much more profitably in the senior year.

Courses might well overlap where repetition would give a new and advantageous viewpoint or a needed emphasis, but any omission of fundamental principles must sooner or later cause serious embarrassment to the student; therefore it is quite important that syllabi be prepared for all courses, and that these synopses be studied individually and collectively, by each teacher and administrator in order to produce the proper ensemble both effectively and efficiently.

Question 15. What is the function and importance of laboratory work? Should it aim to give the student a practical training and readiness in manipulation, or rather to support and clarify the theoretical developments of the classroom and lecture? Should the student there discover his knowledge or verify it?

Typical answers, in approximate order of seniority are as follows:

"Sir Gilbert Parker recently wrote: 'During the last few years, some of us have been wondering whether with life made so mechanically easy as it is, our senses are not losing vitality and usefulness?'—Observation is of two kinds: 1st, Seeing something that is definitely sought; 2nd, Seeing something of interest or value that is not definitely sought. Laboratory work lays stress on the first, but in order to develop the second, and perhaps in after-life the most valuable kind of observation, other available means should be taken. Fortunately, such means may be applied without the need of expensive specialized laboratories. . . . . The question of time and laboratory room will probably preclude the possibility of having the student do more than verify in the laboratory what he has already learned elsewhere."

"That of a hammer to a rivet. Practical training primarily, clarify theory secondarily. Both necessary. Students *verify* knowledge in laboratory, not discover it."

"First, verification of principles learned in classroom; second, learning commercial methods of testing."

"I understand laboratory work to be for certain subjects, what shop work is to mechanics. The object of all practical work should be to teach the student how to do things. Much good theoretical knowledge goes to waste for lack of ability or knowledge in applying it to practical ends.

"It is impossible to give a man enough laboratory work in a college course to make him skillful in manipulations. That is more the function of a trade school."

"The laboratory and the classroom should be coördinate. . . . . College is not the place to study manipulations, as it can be done very quickly in practise."

"There is a great tendency to make routine of it in large schools, taking away initiative."

"Laboratory work should do both. Student should rather discover his knowledge than verify it. The verification has a certain value in adding confidence. This may be necessary in some items of knowledge, but the student should not waste time verifying items which are almost self-evident from reading."

"Laboratory work materializes the truths studied. It is helpful as a vehicle for representing or expressing these truths as well as a means of quickening and holding interest. If made too prominent it obscures the real truth and makes the thinking sluggish—weighted down with material."

"The first part of the laboratory work should verify, but the advanced work should be along the line of original investigation—manipulative readiness is incidental."

"It is of course impossible to give a broad experience at college, but sufficient can be taught to prevent a man from making a fool of himself later on, and give him that foundation on which to build his later structure of experience."

"Laboratory work, shorn of drudgery, and with a clear and definite object in view, is good."

"See Doctor Lucke's paper on 'Function of Laboratory Courses,' before the Amer. Soc. Mech. Engrs."

"To give full value it must be done leisurely but in a businesslike way under the intimate direction of a thoroughly competent instructor. Done otherwise, it may prove even positively detrimental."

"A great deal of time devoted to laboratory work would be better omitted and, in its place, matters such as economics and philosophy should be substituted. A week's time in a work shop or laboratory after leaving school will, as a rule, give a young engineer more practical experience and more practical demonstration of his theory than the average laboratory course which takes up much of his valuable time in college."

"The function and importance of laboratory work will depend on the nature of the course. In many courses its object should be to clarify the classroom work but in other courses such as assaying and surveying, its aim is to give the student a practical training and readiness in manipulation."

"The laboratory should serve as a filter for clarifying the students' ideas—removing the haze. . . . . One experiment thoroughly done is worth more than a dozen superficially skimmed through."

"The first function of laboratory work should be to impress upon the student that it is possible by experiment to prove most things as to which doubt or question has occurred to him. Student should be encouraged to originate experiments of his own provided they are of such a nature as to offer information after they are carried out.

"Too much surveying cannot be given, to make a good civil engineer."

"If the student is made to *discover* his knowledge, it will remain forever."

"Both. Verify first, which will lead to discovery."

"In the walks of our profession we have to discover our knowledge. I would let the student do it this way wherever practicable."

"Laboratory work is of value in supporting and clarifying the theoretical developments of the classroom and also to give the student some confidence in his ability to apply his theoretical knowledge."

"Student should discover his knowledge rather than verify it, since this leads to the development of ingenuity and resourcefulness."

"Should serve the purposes of *interesting* the student in his theoretical work and *fixing* theories in his mind. I have found that to actually handle an instrument or piece of apparatus is worth a considerable amount of descriptive matter in a book."

"As important as either of the functions mentioned in the question is the training which the work should give in the formulation of clear, systematic, condensed reports."

"The average student has too small an 'apperception mass' to find out much for himself in the laboratory in the time allotted."

"In the mechanical laboratories, definite problems should be given to the men to solve and it is at this point especially that accurate and well-written reports covering all the details and conclusions should be demanded. It is a well-known fact that the average engineering graduate cannot put on paper a well-balanced report of an investigation. It is one of the legitimate purposes of the engineering schools to teach them this very thing; and such reports should receive the careful attention of the men in charge of the various departments and be scrutinized not only for technical accuracy but also for English, for conciseness, logical arrangement and, above all, for proper balance of the weight given to the important items."

"Viewing my own undergraduate work in the light of my subsequent experience, I believe that one of the greatest aids for promoting the efficiency of technical instruction lies not with the faculty or with the course of study or with laboratory facilities, but with the students themselves. Too many are not in earnest with their work and refuse to consider their assignments seriously. In other words, the majority do not have the ambition to really become engineers. A feeling prevails that a good student will never be successful because he is not practical. It has been my observation and experience that the graduates in engineering who are and have been successful were good students in college. This fact should be held up before the undergraduate to instill a seriousness of purpose which is in many instances lacking."

"Laboratory work is fine if University methods, not High School methods, are employed. I considered our Physics lab was a joke, and so did the rest of the class. Put a little ginger into these courses and a live wire in charge, and watch results. The steam laboratory work was fine experience. We had to work some, but it was good for us, and I never heard a student complain that the course was dull. . . . . Don't be too hard on the fellows who fail to get absolute accuracy in their notebooks. Many a student who has drawn an 'A' in lab work on a perfect notebook couldn't get one of his fellows to endorse his note for five cents. This hurts the man who puts down results as he gets them."

"He should verify his knowledge there rather than discover it. . . . . The average laboratory assistant of twenty-three knows more chemistry than the alchemist of old had learned after experiments and reflections covering half a century."

"The particular 'angle of reflection' from which I view the subject now is that of a man with one year's practise of his profession (mechanical engineering) followed by five years of strictly commercial experience—a point of view which will be different from those of most of your correspondents. . . . . It has always been my firm belief that an engineering education is the best training for a general business career. There are many men, particularly in the manufacturing businesses, who miss their full possibilities because they have not had the mental training to give them the proper grasp on industrial processes. . . . . The functions of laboratory work should be both those that you mention. One of the most useful courses I had was a little laboratory course tucked in an inconspicuous place in the curriculum and tagged 'Freshman Physics Lab.' We measured steel bars to the thousandths of a millimeter and weighed scraps of paper to the thousandths of a milligram, and learned all about micrometers and verniers and taking the average of numerous observations and estimating subdivisions and all that sort of thing. As far as practical application is concerned, only a watchmaker or an analytical chemist would use these fine adjustments. I have had no use for the practical knowledge obtained except to be able to use a slide-rule with a fair degree of accuracy and read a thermometer on a hot day without being fooled by parallax. But the training of that course gave me an entirely different perspective on physical values that has been immensely helpful in many indirect ways."

"One of the most important things that can be taught in laboratory work is the method of working up data and writing a clear, concise and complete report, requiring some individuality in the report, not the mere copying of a form."

"To demonstrate those phenomena which cannot be understood thoroughly unless seen."

"College professors should be interested in some line of laboratory research and should require the help of students."

"Laboratory work should verify what the student has already deduced."

"The attempt to 'lead' students into the discovery of the great truths of the laboratory results too frequently in their making erroneous deductions. The better way would be to have the practical work of an experimental nature follow the lecture in the corresponding matter as closely as possible, perhaps under the personal direction of the instructor who has presented the theoretical portion. Instead of *every* student being expected to do *every* experiment, equally good results and more rational deductions could be expected by having a few students perform the experiment *once*, in the presence of all, and under the direct observation of the instructor."

"Its function is to enable the student to theorize more practically."

"Laboratory work does drive the theory home and adds many fine points overlooked in the study of the text."

"A student's time is too valuable to acquire knowledge by the slow process of experimenting."

"I do not believe it is possible to make an engineer from book study alone."

SUMMARY: Some thoughts in relation to laboratory work were brought out in answers to the seventh question, which will not be discussed again here. The specific replies to the question now under consideration have been quoted rather freely, and the chief purpose of a summary is to compare and correlate them. Opinion is almost unanimous that the prime purpose of labora-

tory work is to support and clarify the theoretical developments of the classroom. While few believe that practical training and readiness in manipulations should be a purpose or aim of laboratory work, many believe that this function may be or should be fulfilled in conjunction with the prime object. As one correspondent reminds us, it evidently depends to some extent upon the line of work, for a mining engineer or a metallurgical or chemical engineer should be fairly clever at assaying or chemical manipulations, as the case may require.

The value of laboratory work is estimated differently by various men. In fact, the good that a student gets out of *any* course depends upon his viewpoints and his thoughtfulness while he is taking the course, and thereafter. Thus, in a physics course which one man thinks is hair-splitting disciplinary drudgery, another man finds lessons which are of great value in fields far removed from physics—because he thinks about his work and feels the spirit of it. There is a good lesson or moral there, for all students of all subjects; if the comparatively brief college experience is to be to any great extent useful in after life, it must be through skillful interpretation and adaptation.

Laboratory time is usually so expensive to both the student and the school, that none can be afforded for the purpose of developing or teaching commercial methods or skill in testing. It is well spent, however, in training the student to notice things and then to think about them, to arrange, improvise, invent, and persist in overcoming obstacles, and to think straight amid activity, noise, and other distractions. Laboratory work should not be desultory, but should start always from definite objects clearly defined, and should proceed in as quiet, orderly and businesslike manner as possible without waste of time.

It seems that the purpose of laboratory work should be well served, and much interest added, if students were encouraged to originate and perform experiments for settling many of their own doubts and questions; however, no experimenting should be permitted until after they have thought the matter out as far as possible, and have received the sanction of an instructor. Finally, the report is a most important factor of any laboratory work,

provided the requirements be designed to force the student to think. Not the least values of reports are, that the student uncovers thereby many defects in his knowledge previously unsuspected, and that he develops experience and facility in the use of language to express his thoughts.

Question 14. What value do you attach to shop work in an engineer's course, presuming that the kind of shop work is adjusted to the needs of the profession for which in general he is preparing himself? What kind of shop practice for your own line of work? Is two afternoons per week for two semesters or one entire school year too much or too little?

"I regard shop training as vauable for two reasons: first, the discipline and training of hand and eye; second, the acquiring of a familiarity with modern shop methods. An average of three afternoons per week for two years is not too much for mechanical and electrical engineers. Civil and chemical engineers should take about half of this."

"Shop work should be utilized as much as practicable in the course, but in general, I most strongly believe in the advantages of actual work of various kinds preceding college and during vacations, which would develop knowledge of using tools, of doing things, of simple principles of machinery, of repairs, and developing, if possible, the ingenious side of the student. Farm work, carpenter, machine, engineering shops, almost any practical work the better fits a young man to get the most out of a college course, and the greater variety the better."

"I consider shop work very important. Should be supplemented by work during vacations in industrial shops."

"I believe fully that every engineer should know how to do something well with his hands in the shop. It is not necessary that he do manual labor for an extended time but if he is to direct and design engineering work he should have at first hand the knowledge of practical workmanship and of the difficulties to be met and overcome, which can best be acquired by actually learning how to do some one manual task well with his own hands. My own line of work has been largely bridges, both substructure and superstructure, structural work and reënforced concrete work. In this line, I believe that the engineering course should be so arranged that the student would either in the summer vacation or at some other time, have a total of say six months actual practise in the various lines of bridge work. If he can spend three months in a bridge shop punching, driving rivets, laying out, etc., and several months on an erection gang he will obtain an experience that will be of tremendous value throughout his professional career."

"Shop work of the manual-training and exercise type should be relegated to the high schools, and only the laboratory and experimental side of shop work left in the professional college course. The amount suggested in the question is too little for M.E. and E.E. students."

"In mining engineering a limited amount of shop work in forge and machine shop is desirable, if time will permit. Two afternoons per week for two semesters should be ample for mining engineers."

"When I went to college too much time was spent in shop and field work. Months are spent in the average engineering school in making surveys, for example, when the graduate will learn far more in the same number of *days* when he gets a job of driving stakes for some 'rough neck' who never saw college but who can handle an instrument about three times as fast as a college professor. Matters of manual dexterity can best be learned after graduation, from those who are adepts in their line but may know little else."

"Shopwork is essential for mechanical and electrical engineers; it is not essential, but is very desirable, for civil engineers."

"Very great value. For mechanical engineering, general knowledge of shop processes, familiarity with the shop atmosphere and ways of thought. Two afternoons per week for one year is grossly too little."

"Shopwork should be specialized for the different kinds of students, more than it is. The colleges can take many pointers from the trade schools in this matter. I have found it advisable to give electrical engineers a course in

house-wiring, which is a combined textbook and laboratory course. This includes actual wiring construction and testing of the finished work. The construction of electrical machinery is not very well suited to the limitations of a college shop, but should prove beneficial if it can be carried on. The danger of all shop work is that it consumes too much time when complete machines are made, and the making of exercises is of no great interest to the college man. The aim of shop instruction should be the illustration of the use of tools and construction processes, rather than the making of skilled workmen."

"Another serious handicap is the lack of practical experience in shop work, meaning more particularly the association with working men and shop methods before going to college. The ability to handle men is difficult to acquire if one does not have the contact with them while young."

"For civil engineers, cut out the shop work. Substitute all the field work you can. Use two or three months of good weather in actual surveys. Don't depend on three hours three times a week. Make an actual problem of it. Get actual section corners, go to county records and look them up, etc. They will need instructions on the first one; the second or third they should handle independently."

"Particular stress should be placed upon imparting a knowledge of the capacity of tools and the methods to be applied. The latter particularly with the view of having student know that a certain procedure is economical when one piece is being manufactured, but that a different procedure is required when a large number of pieces of the same kind will be made."

"Half of the time so used now could be better spent on business instructions."

"Shop work for engineers should emphasize methods of manufacture and of building, costs of equipment and manufacture, etc., rather than manipulation of tools."

"Shopwork had better be sacrificed to theory. The shopwork which is given in colleges counts for very little in business life, and *if* shopwork *is necessary* for the student after graduation, he usually is compelled to spend a specified time in the shops regardless of what he may have had during his college course. The *commercial side* of shop work is all-important—how much work should a man do on a machine per day. This cannot be taught in colleges, but can only be obtained in actual shop practise where the output is on a commercial basis—and the judgment developed in this kind of shop practise is really the shop work that is necessary."

"I would favor the 'part time' method where possible, i.e., having the student obtain this part of his education in a practical shop."

"The engineer should know how to use all shop tools and equipment that enter into the work of his profession."

"Shop work is very important for an engineer, but there is no reason why a large amount of it should not have been obtained in a manual or technical high school preceding entrance or as practical shop work in one or more of the summer vacations. Two afternoons per week for two semesters is not enough."

"In most executive positions a knowledge of the methods which must be carried out in the shop by one's subordinates makes for greater success and creates a feeling throughout the organization that the Executive is familiar with the work of all his subordinates."

"Furthermore, an interest in mills, factories, etc., should be awakened and encouraged in the student so that he will be disposed to observe and investigate on his own initiative when opportunity offers."

"Under 'shop work' I assume you also include field work, such as surveying. Work of this kind should be concentrated as much as possible and be continuous. That is, I think it would be well to set aside one semester or a portion of a semester for such work exclusively. I recall that the least efficient work I did at college was in the field, shop and laboratory, because the periods were too short and at the end of the period there may have been a recitation or an examination to worry about. It takes a considerable portion of the ordinary two hour period to get instruments out and put them back, and what you have learned you haven't time to digest because the next recitation dismisses it from your mind. . . . . On the whole, less work should be done, but this more thoroughly."

"I consider that two afternoons per week for two years is about right for shop work in a mechanical engineering course. In my case this shop work came so early in the course and I was so young that I did not get the full value of the time spent in the shops."

"Shop work is valuable in giving a man confidence when dealing with men engaged in that line of work. . . . . I should think that two afternoons per week for two semesters was too little. I should say four semesters."

"One afternoon per week for one year is enough."

"Shopwork in engineers' course has no value whatever. Average student will benefit more by shop visits under the direction of instructors, than by any amount of actual shop work."

"A little practical knowledge of handling materials gives an appreciation of the work of others."

"Give engineers practical ideas in regard to manufacturing costs, and whether machines are properly designed and feasible to make."

"I would put shop work very low in value as an adjunct of an engineering course. . . . . In my course (mechanical engineering) there was no actual shop work—only visits of inspection to various manufacturing plants—and I do not feel any loss through its omission."

"Most important but not to be placed in the summer vacation. It is hard for me to conceive of a more farcical thing than the shop visits in July. Shop *work* which puts into immediate practise the things learned in the course is the needful thing. The amount specified is far too small."

"Though no effort should be made to make expert mechanics of engineering students it will do them considerable good to be taught how to use their hands and heads at the same time."

"I doubt if shopwork, as commonly taught, is worthy of University credit."

"The idea of having a student work a full day for a number of weeks, I like better than an afternoon or two a week for a whole year. . . . . Where he works 8 hours per day or 44 hours per week, for four weeks, and has no class work to bother him he will be able to do a great deal."

"In general, shop work is a waste of time. The thing a man can get in a University which he cannot get elsewhere is theory and mental training, and he should concentrate on such things as most greatly promote these."

"Shop work on a practical scale would be of untold value. I have never seen it on that scale. Ordinarily does little beyond give a vocabulary."

"It seems to me there is no more use in an engineering student spending valuable time learning to run machine tools than there would be for a law student to spend the same amount of time learning stenography. In each profession the trained man should expect to hire someone that can handle these details better than he could."

"For the electrical engineer it would be well to embody a course in shop work called 'trouble shooting.' This would cover the location of breakdowns of electrical apparatus and circuits of all kinds, and the repairs necessary to put the same in working order."

"Shop work is a high school subject and any advance work should be optional, for very few men ever use it after leaving college. If the graduate locates in a union community he is not allowed to use it in work for anyone but himself."

"Don't waste time trying to turn out a shaft 1.005" in diameter and 6.01" long. Familiarize yourself with tools, electric wiring appliances, telephone installations, etc. Eight hours per week is not too much shop."

SUMMARY: Our correspondents almost unanimously condemn the manual training idea in shop work, which aims merely (or mainly) to develop skill in the use of hands and tools; they believe the shop-laboratory idea is far better for engineering colleges, where the students seek skill of a higher order and are able to acquire it. Two afternoons per week for two semesters appears to be none too much; many believe that mechanical and electrical engineering students should have more than this, civil engineers less or none.

A significant number of graduates think that the time they spent in shop work at college was wasted, through inefficient instruction from men who did not understand the purpose of the instruction and were neither expert workmen nor competent teachers; this in fact is likely to develop a serious situation, that

the changed conditions demand from our faithful old-school shop foreman instructors new services which overtax their knowledge and ability. Possibly some of the teachers of engineering may help in meeting the difficulty by conducting tours and visits of inspection to well managed shops and factories, by assigning to be worked out by the student in the shops such problems as an engineer might be required to face, and by devising certain kinds of shop work such as wiring, piping, assembling or erecting, to be done in the engineering laboratories.

According to the experience and testimony of our correspondents, the college student finds value in the shop work through the knowledge of shop methods and atmosphere and of the psychology of shop workmen, which he may acquire; through the personal respect and conscientious service which he may be able to demand and receive from his subordinates in engineering or other work, because he has learned something about the difficulties and limitations in the practical work of carrying out such orders as he may give—about what a man should be able to do or should not be asked to do; through the interest in shops and factories and their methods, which may be aroused in him; and through the training of his hand and eye so that they can work in coöperation with his head. To accomplish these purposes it is much better to obtain the shop experience by serving workman's time in practical shops before entering college or during vacations, rather than to obtain it in college shops and in small driblets during school time.

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